UNIVERSITY OF LEEDS

MARS – Strategic Transport Model for Greater Jakarta

Simon Shepherd, Chandra Balijepalli, and
Pauli Pfaffenbichler

January 2018

Project Funded by
International Networks and Collaborations within RIS, University of Leeds.

Project executed in cooperation with
Greater Jakarta Transport Authority

Institute for Transport Studies

INSTITUTE FOR TRANSPORT STUDIES
DOCUMENT CONTROL INFORMATION

Title	MARS – Strategic Transport Model for Greater Jakarta
Authors	Simon Shepherd, Chandra Balijepalli, Pauli Pfaffenbichler
Editor	Simon Shepherd
Version Number	0.1
Date	08/01/18
Distribution	ITS, TUW, GJTA
Availability	Public
File	Mars-Jakarta-v3.doc
Signature	

Table of Contents

MARS – STRATEGIC TRANSPORT MODEL FOR GREATER JAKARTA

1 Introduction

This report provides a summary of the development of the MARS model for the Greater Jakarta Transport Authority. The project was funded by the Leeds University International Networks and Collaborations within RIS and the model was developed under licence with the Technical University of Vienna. Prof Simon Shepherd (PI) and Dr Chandra Balijepalli (Co-I) have developed the model with support from Dr Pauli Pfaffenbichler (TUW) for the Greater Jakarta region which has a population of around 30M. The aim of the model is to contribute to the Presidential Decree 103:2015 Transportation Grand Design for Greater Jakarta and thus support the development of Transportation Master Plan. The model development included construction of a Business as Usual or Do-nothing baseline calibrated and validated to historic data from 2010-2016. It then included development of specific policy scenarios as specified in the Presidential Decree. These policy options involve large infrastructure projects e.g. Mass Rapid Transit (North-South and East-West Lines), extensive Light Rail Transit network within the centre of Jakarta with an extension to Soekarno-Hatta International Airport and road capacity expansion e.g. Jakarta Outer Ring Road. The policy options also include demand management options such as Electronic Road Pricing on a number of roads in and around Jakarta City. Initial results for these policy tests are included in this report.

The rest of this report is structured as follows, the next section gives some background to the planning situation and key performance indicators for the Greater Jakarta region, section three gives a brief introduction to the MARS model, section four describes the validation/calibration process for the BAU case, section five describes the policy measures implemented and section six shows the results from implementing these policies.

2 The Greater Jakarta Transport background and KPIs

According to the Ministry of Transport (MOT) of the Republic of Indonesia, Greater Jakarta is populated with 27,700,727 people - with an average density of 4,585 people per square km. In 2014 alone, Jakarta residents made 10.86 million trips every day, and the number is expected to grow by 3 to 4 percent every year. Congestion is beginning to spread towards Jakarta's satellite cities, and those who work in the middle of the city have it worst because every day, millions of workers from Depok, Bogor, Bekasi and Tangerang - who have been priced out from the city centre - use their private vehicles to commute to work.

The use of private vehicles in Greater Jakarta is expected to increase by 40 percent in 2020 according to a 2012 study known as Jabodetabek Public Transportation Policy Implementation Strategy (JAPTAPIS). At the same time the utilization of public transportation is expected to drop by 18.5% within the same period. As a result, the average speed within the city is expected to drop to 8.4 kilometres per hour - a staggering 35.6% percent dip between 2010-2020, Jakarta needs to be much more integrated and that a multi-faceted solution that encompasses better town planning, as well as higher levels of transportation and infrastructure organization is desperately needed - a discussion that has been on the table since 1974 but has not made any significant headway since.

Following an initial scoping study in November 2015 set up by the MOT in Jakarta where ITS presented the model of MARS, it was agreed that MARS would be useful to test future transport and land use policies including METRO extensions, BRT extensions, Pricing and other policies. In particular it was seen as an essential tool to be used in the newly formed GJTA which has the remit to develop and implement master plans for land use and transport in collaboration with the 9 Authorities surrounding Jakarta. As such this situation mirrors ITS' experience in West Yorkshire and the associated research with MARS into competing cities where they demonstrated the benefits of collaboration over competition.

The project which involved developing MARS model for Jakarta is timely too. In response to the growing concerns over congestion in the capital region of the country, the President of Indonesia took initiative and declared their policy. The top level initiative combines nine local authorities to form JaBoDeTaBek henceforth to work together to coordinate the land use development and to offer services including transport in a seamless manner. In particular a new unified body called Greater Jakarta Transport Authority (GJTA) has been formed with the aim 'To develop, manage and improve integrated transport services in Greater Jakarta area (Jakarta, Bogor, Depok, Tangerang, and Bekasi)'. To execute its duties, GJTA refers to Transportation Grand Design for Greater Jakarta ('Presidential Decree').

The Presidential Decree 103:2015 also specifies very broad-level key performance indicators (KPI's) as below:

'Public transport share is 60 %

Maximum travel time from origin to destination is 1.5 hours at peak hours.

Minimum average speed is 30 km / h at peak hours.

Coverage of public transport services in urban areas is 80 % of the length of the road.

Maximum walking distance to public transport is 500 m.

Each region must have feeder line connected to the trunk line in transit point.

The transit must have facilities for pedestrians and car park and ride, with the maximum transfer distance between modes is 500 m.'

The MARS model will inform the planning of new policies and how to tackle the short-comings of transport planning. The model is able to assess the new Metro system in Jakarta, extension of commuter rail line, new LRT system, Bus Rapid Transit, parking charges, ERP tolling system and land use policies in a context of rapid urban growth. It can also be used to demonstrate the benefits of collaboration in the region rather than competition and aid the development of the new governance structure. It is seen as an essential tool for better planning. Once applied in the Jakarta region it can then easily be transferred to other regions in Indonesia, e.g. Bandung, Lampung, Surabaya and Yogyakarta.

3 The MARS model

MARS is a dynamic Land Use and Transport Integrated model. The basic underlying hypothesis of MARS is that settlements and activities within them are self organising systems. MARS is based on the principles of systems dynamics (Sterman 2000) and synergetics (Haken 1983). The development of MARS started around the year 1999 partly funded by a series of EU-research projects. To date MARS has been applied to ten European cities (Bari, Edinburgh, Gateshead, Helsinki, Leeds, Madrid, Oslo, Stockholm, Trondheim and Vienna) and three Asian cities (Chiang Mai and Ubon Ratchathani in Thailand and Hanoi in Vietnam). Two more models have been developed in the USA and Brazil. The present version of MARS is implemented in Vensim®, a System Dynamics programming environment. This environment was designed specifically for dynamic problems, and is therefore an ideal tool to model dynamic processes.

MARS is a strategic land use – transport interaction model capable of analysing policy combinations at the city/regional level and assessing their impacts over a 30 year planning period in less than one minute. Figure 1 shows the basic structure of the model. It includes a transport model which simulates the travel behaviour of the population related to their housing and workplace location, a housing development model, a household location choice model, a workplace development model, a workplace location choice model, as well as a fuel consumption and emission model. The sub-models are run iteratively over a 30 year time period. They are linked on the one hand by accessibility as output of the transport model and input into the land use model and on the other hand by the population and workplace distribution as output of the land use model and input into the transport model. A comprehensive description of MARS can be found in Pfaffenbichler (2003) or Pfaffenbichler et al (2008), Pfaffenbichler et al, (2010). The model has been transferred to a system dynamics platform VENSIM which provides a transparent approach to model development. The flight simulator approach allows users to change policies and view outputs in a simulation environment with easy to use "slider bars". Outputs are presented in graphical and tabular format with a new link to animated mapping software (Animap). In addition the user may use the VENSIM optimisation facility to optimise a package of policy instruments against a given set of objectives or targets.

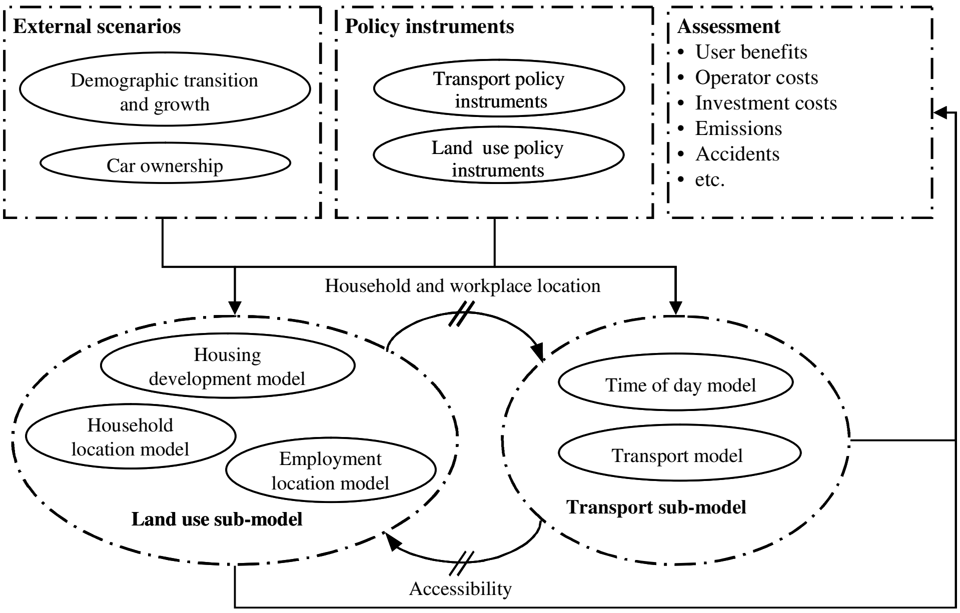


Figure 1: Basic structure of the MARS sub-models

The model is built using the Causal Loop Diagram (CLD) technique to improve transparency. Figure 2 shows the CLD for the factors which affect the number of commute trips taken by car from one zone to another. From Figure 2 we start with loop B1 which is a balancing feedback loop. In it, commute trips by car increase as the attractiveness by car increases which in turn increases the search time for a parking space which then decreases the attractiveness of car use – hence the balancing nature of the loop. Loop B2 represents the effect of congestion – as trips by car increase speeds decrease, times increase and so attractiveness is decreased. Loop B3 show the impact on fuel costs, in our urban case as speeds increase fuel consumption is decreased – again we have a balancing feedback.

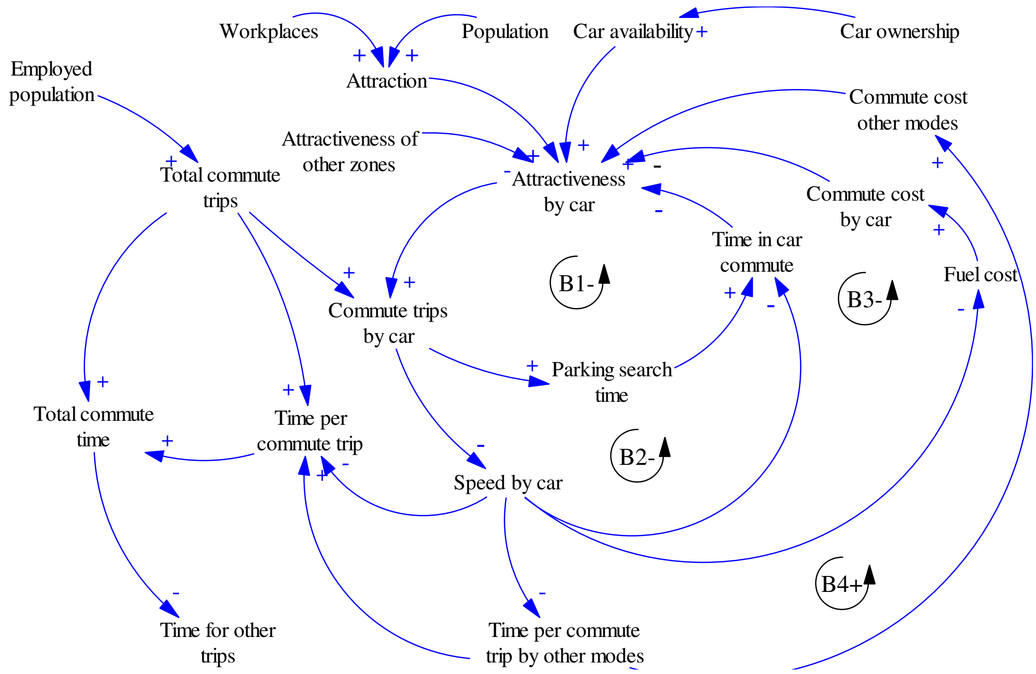


Figure 2: CLD for the transport model – commute trips by car in MARS

Recent enhancements to the model (implemented as part of the DISTILLATE project) include representation of over-crowding, congestion in the off-peak period, representation of a fourth heavy rail mode, the impact of bus quality factors and awareness campaigns. These improvements are reported in Shepherd et al, (2007).

The other major barrier which can be overcome with MARS is that of ease and speed of use and presentation to stakeholders. The model has been transferred to a system dynamics platform VENSIM® which provides a transparent approach to model development.

MARS uses a so called “flight simulator” approach whereby a front-end as shown in Figure 3 is used to control the policy inputs by use of slider bars. This allows the user to test a combination of instruments and to view standard outputs (as shown in Figure 4) within less than one minute. Note that for the Jakarta model, we developed our own sliders within a published model which appear different to those pictured below and that due to the larger number of zones included in the model that the run time is a few minutes. In addition to the standard outputs the user can also animate GIS based data through a specially developed piece of software “Animap” which animates the map based information post simulation (see static view Figure 5). In addition the user may use the VENSIM® optimisation facility to optimise a package of policy instruments against a given set of objectives or targets. Here the user can set bounds on possible instruments, define an objective function or target trajectory for an outcome variable e.g. CO_2 and through the batch run optimisation procedure produce an integrated package which either maximises the objective function or meets the target trajectory.

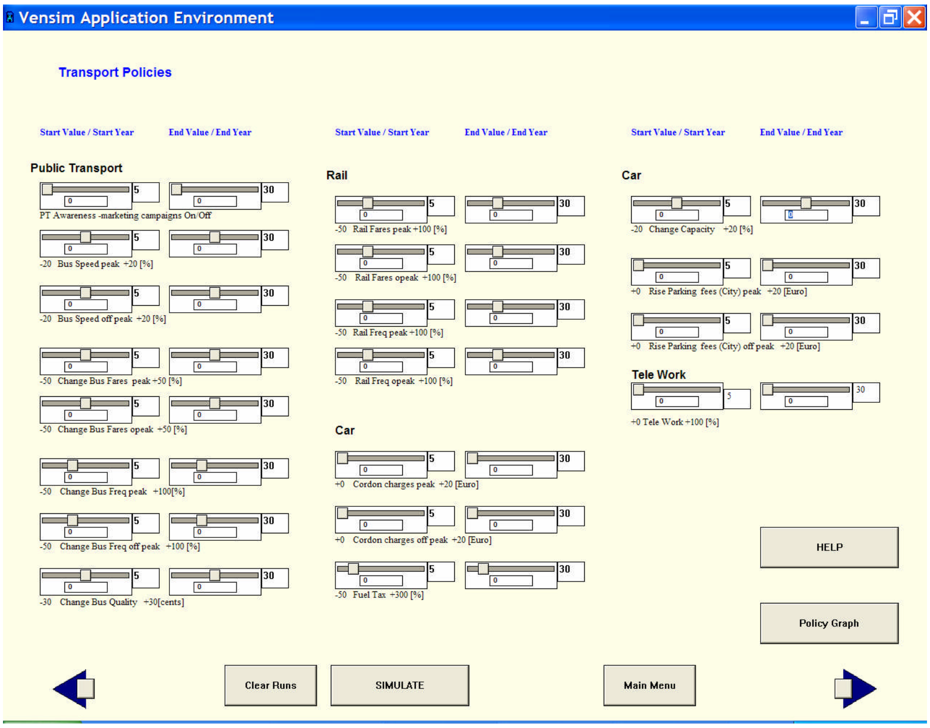


Figure 3: Example of flight simulator front-end for MARS

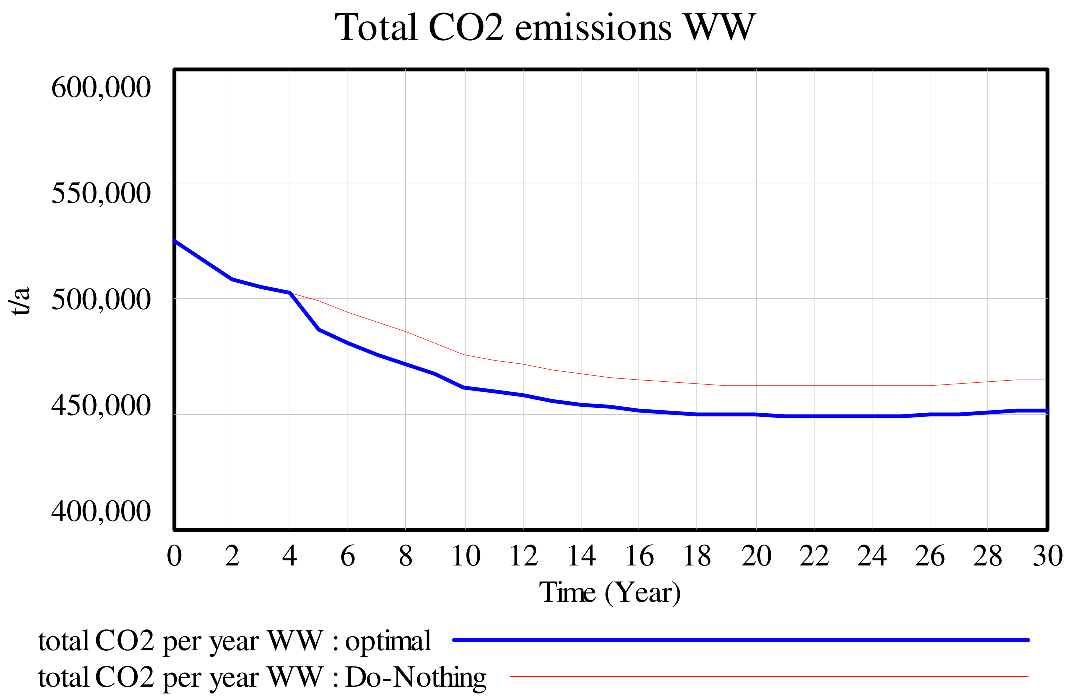


Figure 4: Example outputs from MARS – CO_2 emissions well to wheel

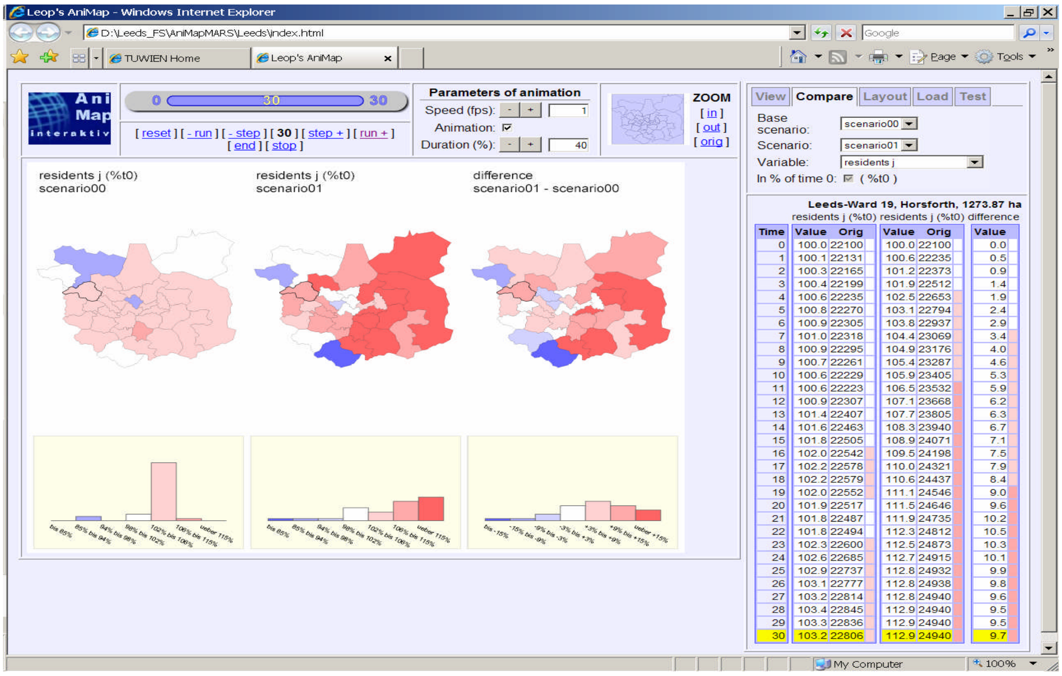


Figure 5: Screen shot from MARS-Animap animation tool.

4 Basic features of Jakarta MARS model

Zoning system: The zoning system was developed in collaboration with GJTA. There are 186 districts in Greater Jakarta which have been regrouped to form a 161 zoning system for the previous JUTPI study. However due to the strategic nature of MARS modelling work we decided to reduce the number of zones significantly in order to suit the available data as well as to facilitate quick scenario comparison. The principle we have followed is to develop a zoning system with sufficient detail in Jakarta city and to have relatively less detail in the outer areas. One of the critical requirements is to be able to undertake policy tests involving improvements to the proposed public transport infrastructure improvements within Central Jakarta. Thus we arrived at an agreed 79-zone system with 42 of them located in Jakarta and the rest from the surrounding local authority areas (Figure 6).

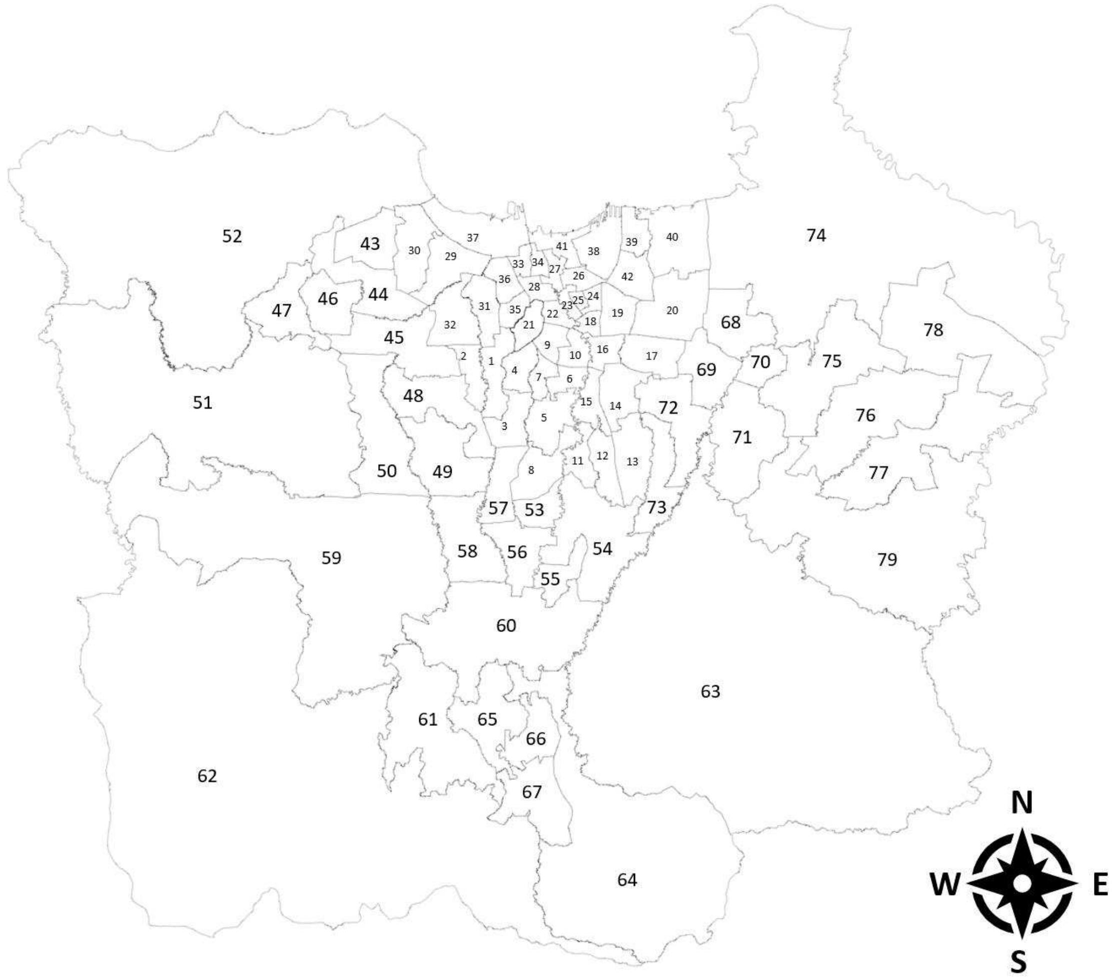


Figure 6: Greater Jakarta zoning system

Based on the available census and other statistics the year 2010 was set as the base year and a 30-year horizon period to 2040 was agreed as the study period.

Currency IDR (in thousands): There are a number of locations where monetary value inputs are needed e.g. household income, rents, public transport fare, parking fees etc. It was agreed to input the monetary values in '000 IDR (e.g. 100000 IDR will be input as 100 IDR). As such the monetary outputs will also need to be read in terms of '000 IDR where applicable.

The MARS model for Jakarta considers two purposes – commuting and non-commuting. As MARS is a tour based model with a travel time budget, time available for non-commuting in a day is computed as the difference between budgeted travel time and the time spent in commuting.

The MARS model simulates the daily travel decisions in two time periods – peak, off-peak.

Transport modes: A range of existing/future transport modes in Jakarta have been incorporated into the model as below.

- private car

- motorcycle
- public transport - BRT, bus
- commuter rail
- active modes: pedestrians/bicycle
- New modes: MRT, LRT

It is noted that the other modes such as taxi, tuk-tuk etc are considered marginal for a strategic model due to their low modal shares but are assumed to be subsumed in flow-delay responses.

5 Business as Usual and validation/calibration

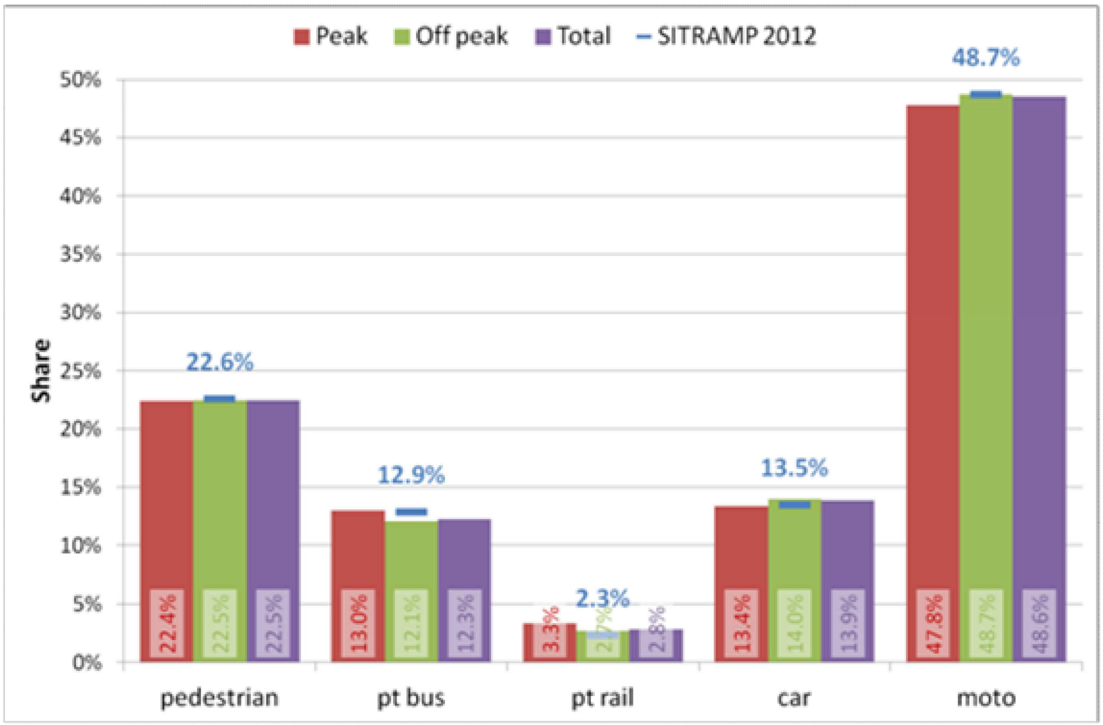
Vensim® offers an automated optimisation routine which can be used to calibrate models. The model MARS-Jakarta v3.2 is first calibrated to fit the overall mode split from the Revision of SITRAMP Transportation Master Plan March 2012 and the zone wise population in 2015. The data for mode split is shown in Table 1. Note that the data was the same for peak and off-peak which limits the model to some extent and is an area for future work but which depends on better time period specific data collection.

Table 1: Calibration modal split 2010

Mode	Peak	Off Peak
Pedestrian	22.6%	22.6%
Bus	12.9%	12.9%
Rail	2.3%	2.3%
Car	13.5%	13.5%
Motorcycle	48.7%	48.7%
Total	100.0%	100.0%

Source: Peak mode split, Fig 2.3.1 & Table 2.3.1 page 9 in 'Revision of SITRAMP Transportation Master Plan March 2012'

Figure 7: shows a comparison of the MARS results for peak, off peak and total mode share with the respective data from SITRAMP. The conformity is very good. The MARS model slightly underestimates the share of bus while slightly overestimating the share of rail. Table 2 gives an overview of the parameters which have been used in the calibration and their values as resulting from the calibration.



Source: Peak mode split, Fig 2.3.1 & Table 2.3.1 page 9 in 'Revision of SITRAMP Transportation Master Plan March 2012', MARS-Jakarta v3.2 results

Figure 7: Comparison of observed and calculated mode split base year

Table 2: Calibration parameters mode split

Mode	Parameter	Peak	Off peak
Walking	alpha pedestrian xls	0.101677	0.128654
Bus	alpha cost bus t=0 xls	0.111492	0.196390
Rail	alpha cost rail t=0 xls	0.250000	0.250000
Car	alpha fuel xls	0.117573	0.100000
	alpha parking/other xls	0.242561	0.100000
Motorcycle	alpha fuel moto xls	0.600000	0.600000
	alpha parking/other moto xls	0.600000	0.600000

The next stage is to calibrate the land use responses within the model. Here the model is run from 2010 to 2015 and parameters are calibrated to get the best fit in 2015 as described below.

Figure 8 :shows a comparison of the MARS results for the zone wise number of residents with the respective data as observed in 2015 for the different phases of the calibration process.

Before calibrating the land use part ("pre calib") a linear regression between the two datasets results in a coefficient of determination R^2 of 0.9824. The slope of the regression line is 0.8413. The offset of the regression line at zero is 41,715 residents. For a perfect fit the slope should be 1, the offset should be 0 and the coefficient of determination R^2 should be 1. In a first step the parameters of the sub-model for the development of housing units have been used to calibrate the model (“calib HU”). The calibration results in a significant improve of the slope (0.8869). The offset (41,766) and the coefficient of determination R^2 (0.9816) remain more or less constant. In a second step the parameters of the sub-model for the willingness of households to move out have been additionally used to calibrate the model (“calib HU & Move out”). This does not contribute to significant further improvements. Finally the parameters of the sub-model willingness of households to move into a zone have been used too in the calibration (”“calib HU & Move out & Move in”). The additional parameters improve the fit significantly. The slope improves to 0.9227, the offset improves to 27,564 and the coefficient of determination R^2 improves to 0.9849. The conformity between model results and observations is good. Table 3 gives an overview of the parameters which have been used in the land use sub-model calibration and their values as resulting from the calibration process. Details of the meanings of these parameters can be found in the full model thesis by Pfaffenbichler (2003).

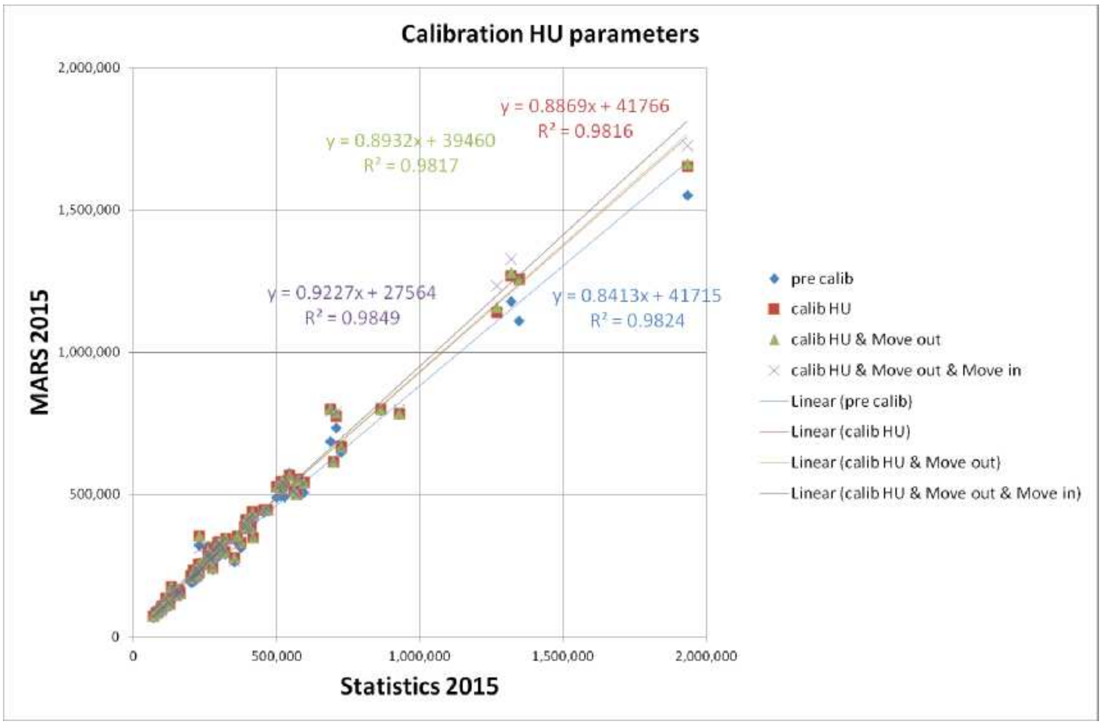


Figure 8 : Comparison of observed and calculated number of residents by zone 2015

Table 3: Calibration parameters residential land use sub-model

Sub-model	Parameter	Value
Development housing units	alpha supply land	0.575
	alpha housing costs	0.1085
	alpha land price	0.01
Household move out	Avg time living at the same location xls	10
	"b(r) out"	0
	"c(r) out"	0
	"d(r) out"	0
Household move in	"a(r) in"	1.85869
	"b(r) in"	2
	"c(r) in"	2
	"d(r) out"	0
	"e(r) in"	-0.01
	"f(r)in"	1.05046
	inc in	5

6 Strategic transport policies for testing

Jakarta public transport network

Jakarta authorities are currently constructing a number of new public transport lines besides expanding the existing commuter rail. The new lines include Mass Rapid Transit and Light Rail Transit. There is also a new link being constructed to connect the airport with city centre. In addition there are a number of extensions to the commuter rail are being executed too. A comprehensive network of public transport links (Figure 9) has been considered for developing alternative infrastructure policy scenarios in MARS. The following describes the details of MRT and LRT systems which went into scenario definitions.

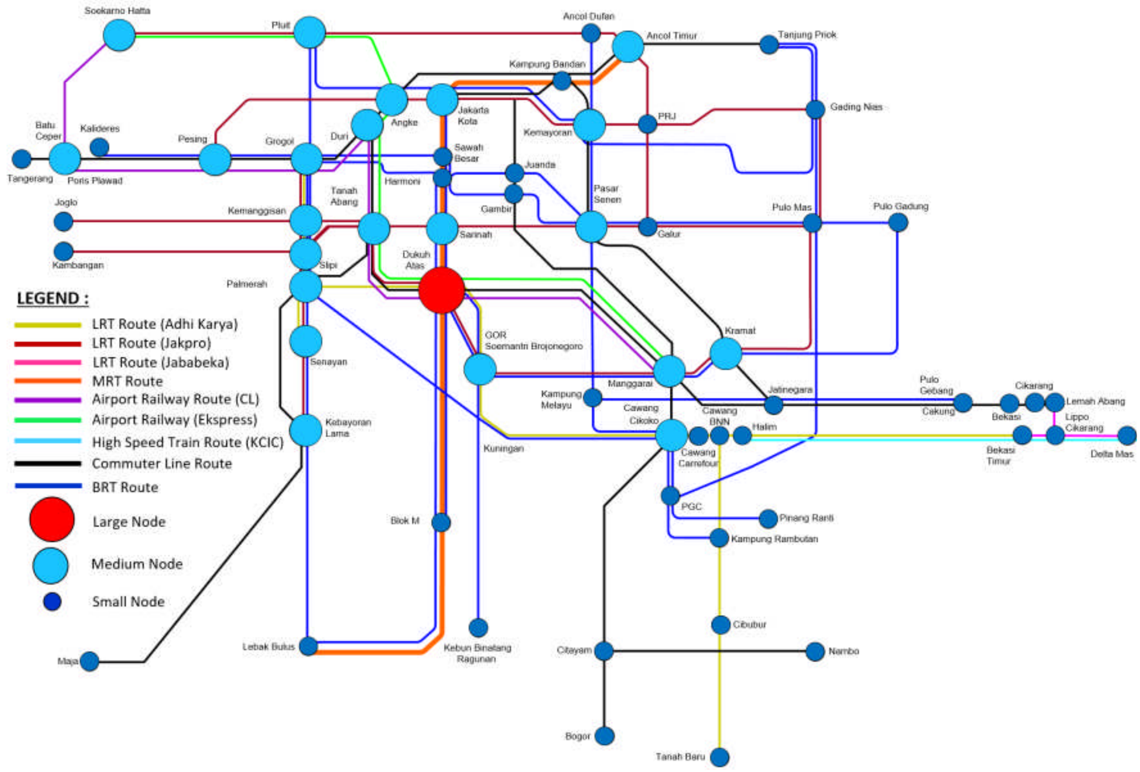


Figure 9 Public transport network input for MARS scenarios

Jakarta Metro: Mass Rapid Transit (MRT) rail line is currently under construction between Lebak Bulus and Kampung Bandan on the North-South corridor (Figure 9). In addition there is also a proposal to develop the metro line further on the East-West corridor. MRT has been specified with the following characteristics for testing purposes in the MARS model. The characteristics used for policy testing are a reflection of various readings from sources such as JICA reports, GJTA's information provided to ITS and the following are therefore our best estimates of parameters and they can be changed easily. Frequency peak 5min

- Frequency off-peak 7.5min
- Fare 8.5k IDR both peak and off-peak
- Changing time at Sarina 10min if need to transfer between North-South/East-West lines
- North-South line to commission by 2018
- East-West line to commence by 2024
- Possible to integrate with KRL/LRT network
- 100 km of network North-South and East-West lines

Table 4 lists the station names on North-South line and maps them to the MARS zoning system.

Table 4: Mapping of Jakarta MRT stations over MARS zones

No	North-South Station Name	Primary Affected MARS Zone No.
1	Lebak Bulus	1, 3
2	Fatmawati	3
3	Cipete Raya	3
4	Haji Nawi	4
5	Pasar Blok A	4
6	Blok M	4
7	Sisingamangaraja	4
8	Senayan	21
9	Bung Karno	21
10	Bendungan Hilir	21
11	Setiabudi	21
12	Dukuh Atas	21
13	Bunderan HI	22
14	**Sarinah**	**22**
15	Monas	28
16	Harmoni	27
17	Sawah Besar	34
18	Mangga Besar	34
19	Glodok	34
20	Kota	34
21	Kampung Bandan	41

Jakarta LRT: Jabodetabek study area has a number of LRT proposals and some of them are currently underway. Jakarta Government Jakpro is involved with constructing Velodrome – Kelapa Gading; MOT/ Adhi Karya are financing Cawang-Cibubur, Cawang-Bekasi Timur and Cawang-Dukuh Atas LRT lines; and LRT Jababeka is also being planned between Bekasi Timur and Delta Mas. In addition to the LRT lines, there will be two rail lines to Seokarno Hatto Airport – an express line via Pluit and another as a commuter rail line extension via Batu Ceper (Figure 9). In the future, proposed LRT lines together with the extensions to the commuter rail line will form a well-integrated public transport network offering seamless journeys in Jakarta and surrounding areas. The main characteristics of the LRT/commuter rail line used within the modelling are as below:

- Integrated fares: fare 4k IDR if LRT alone, 5k if LRT+KRL, otherwise current KRL fares
- Modal integration with KRL - changing time of 5min between LRT/KRL
- LRT lines to commission by 2020
- Primary affected zones have been included (i.e. only zones which contain a station)
- LRT North-South line: 30 stations
- LRT Jabodetabek: 41 stations
- Airport line: 5 stations

- Total length of the network: ~170km

Jakarta road network development strategy

ERP – toll roads

Currently there are a number of toll roads being operated in Jakarta, the network of toll roads is expected to grow significantly in the near future (Figure 10). There are several road projects currently underway e.g. Jakarta Outer Ring Road extension which will be operated as toll roads for cars, buses and lorries but exclude two-wheelers from using the same. With the help of GJTA, all affected zones due to the new road projects have been identified and mapped to form a list of affected OD pairs. A flat toll charge of 5000 IDR has been applied (for illustration purposes) to investigate the impact on modal shares. If an OD pair is already connected by a toll road then the current charge is being increased by 5000 IDR.

The ERP testing scenario considers the existing road capacity increased by 15% to account for the new capacity as new roads are being constructed.

Figure 10 Road network development input for MARS

Other policy options available in MARS

In addition to the tests described so far, there are also a number of other policy tests that could be initiated as indicated below:

Bus

- Fares peak/off-peak +/-
- Frequency peak/off-peak +/-
- Bus lanes peak/off-peak
- Quality/awareness campaigns

Car

- Road capacity +/-
- Parking places +/-
- Parking charges +/-
- Fuel taxes
- Work from home

Motorcycles

Road user charging

Some of these policy tests can be easily undertaken by incorporating the changes needed via policy input slider bars available within MARS model. Others may require some effort in data preparation e.g. using excel. See appendix for more details.

7 Policy results

This section presents the results from various policy test runs but we first start with the BAU scenario as below.

BAU – business as usual

The BAU scenario assumes that no new transport projects are initiated but the residents and jobs will continue to grow due to the economic growth. The MARS model allocates the residents and jobs to various zones based on relative attractiveness of living/working and availability of land for development in a zone. Figure 11 shows the change in number of residents in Greater Jakarta from year 2010 to year 2040 in steps of 6 years (red indicates an increase and blue a drop in residents). In the initial stages the residential densities are higher in central Jakarta but as time passes, the outer areas gain in densities indicating an urban sprawl. This happens because the central areas are very attractive to live/work, but they will be unaffordable to many. Thus the new growth will all be focused in areas largely along the

East-West and North-South axes. Some zones e.g. 59 in the west, 62 in South-West and 79 on the east however will experience an outward migration to other areas along the North-South or East-West axes.

Figure 12 shows how the service employment changes over space and time in Greater Jakarta. It is predicted that the number of jobs will spread out to various parts of Greater Jakarta by year 2040 which is a positive development in itself. But it is noted that a large proportion of the job spread is related to the service employment. Thus as the industry and manufacturing jobs located in central zones remain as before (not shown), residents will continue to travel across to the central areas thus adding to the pressure on the already over-crowded transport system.

It is useful to note that the exogenous growth in population/jobs as below is an over powering factor that needs to be absorbed by the land use/transport system in Jakarta:

- Population growing at 1.1% pa from 28M to 38M by 2040
- Positive growth in economy indicated by a good employment growth from 11.2M in 2010 to 15M by 2040

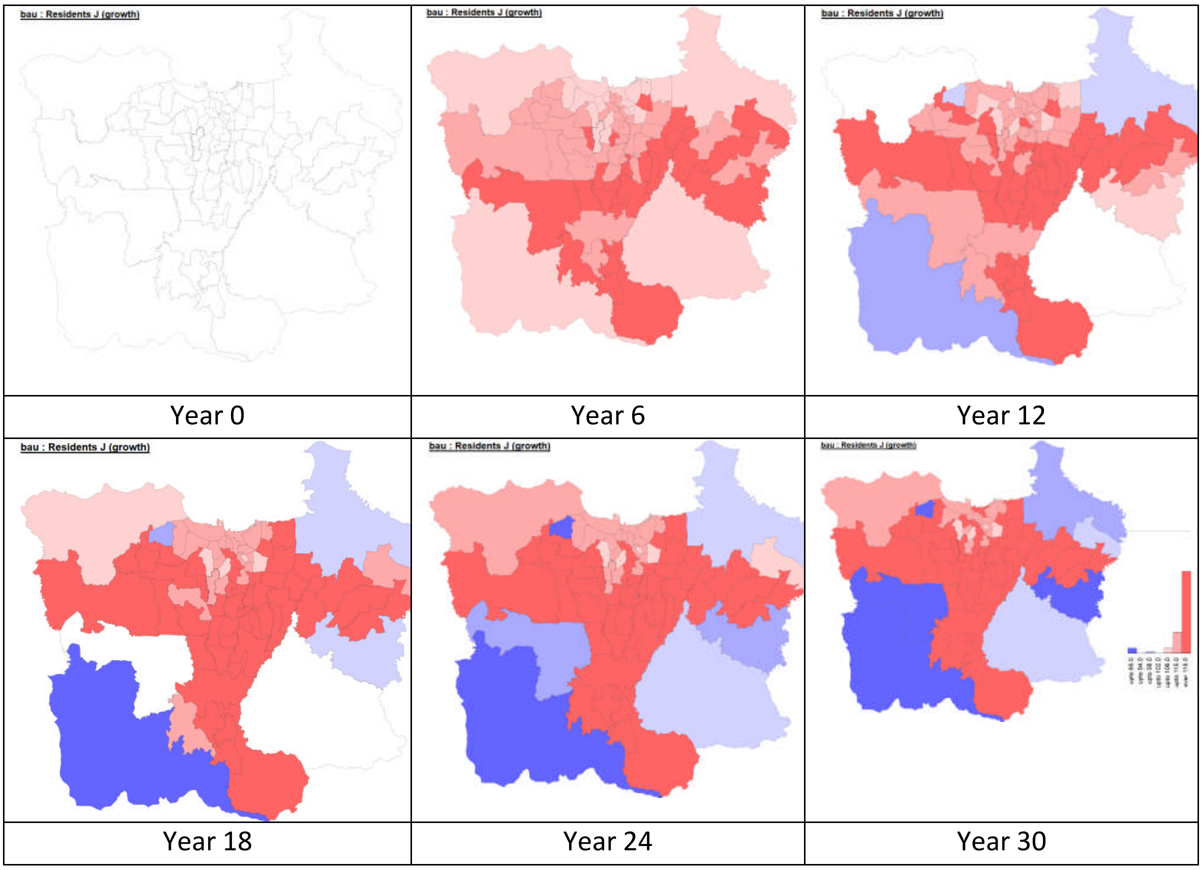


Figure 11 Growth in number of residents in Greater Jakarta

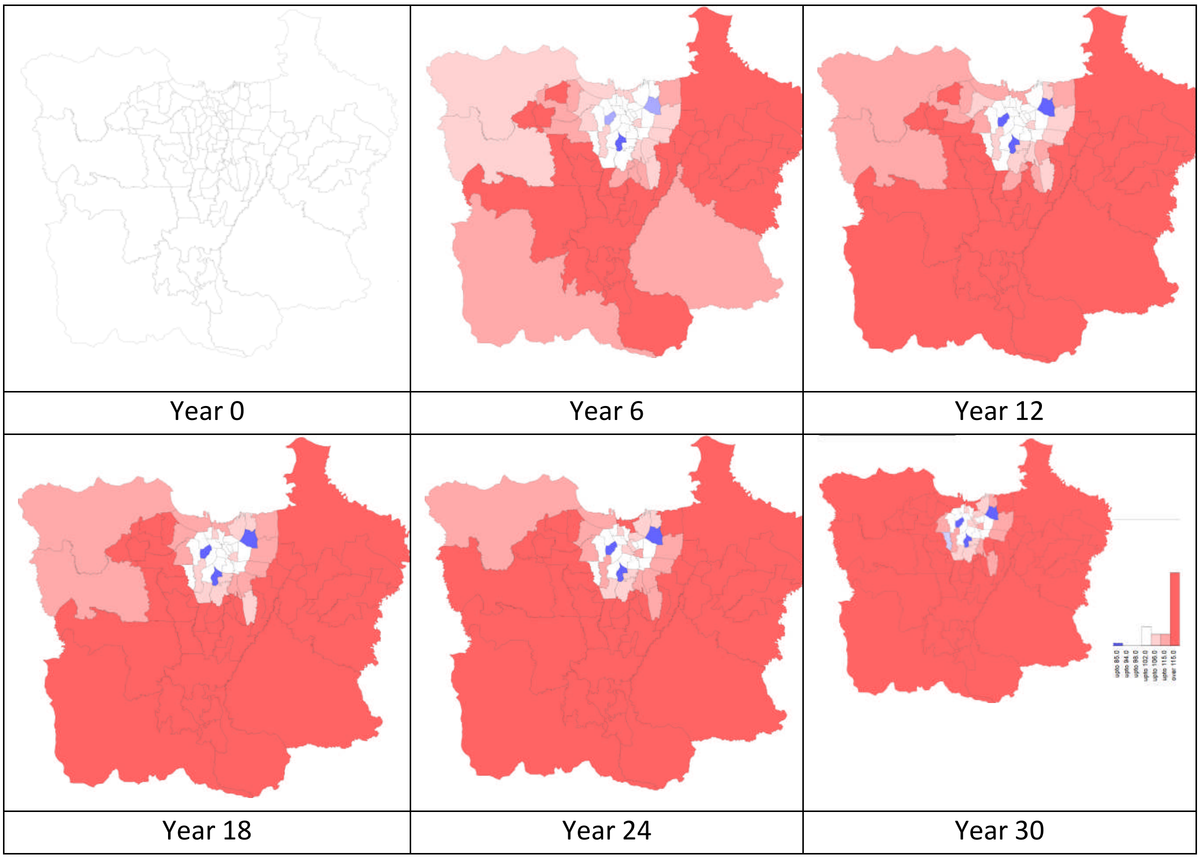


Figure 12 Temporal changes in service employment in Greater Jakarta

Exogenous growth in economy also results in an increase in car and motorcycle ownership in Jakarta as shown in Figures 13, and 14. Car owning rate is predicted to increase from 100 cars/1000 persons to about 300 cars/1000 persons, while the motorcycle owning is expected to reach 700/1000 persons by year 2040. Thus the external factors controlling the growth of private vehicles are extremely important and can significantly affect not only the BAU but also all the other future scenarios.

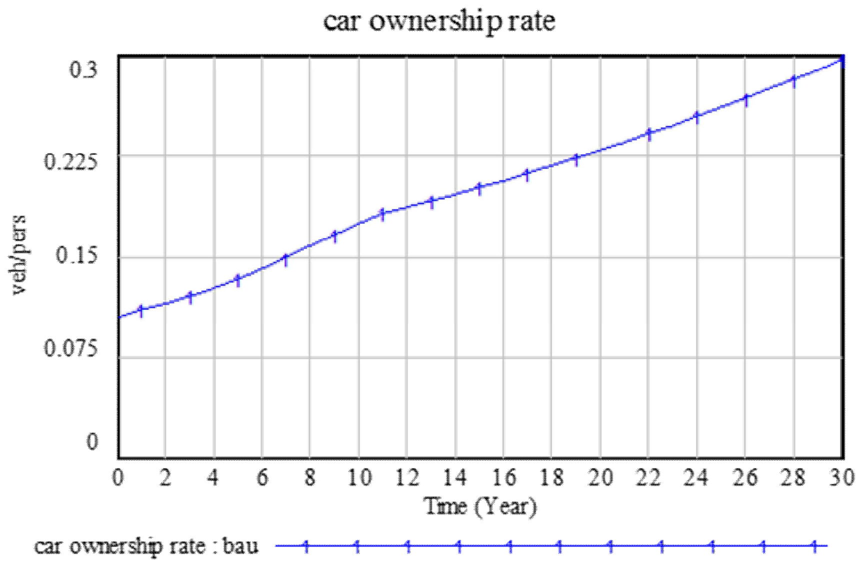


Figure 13 Car ownership growth in Greater Jakarta

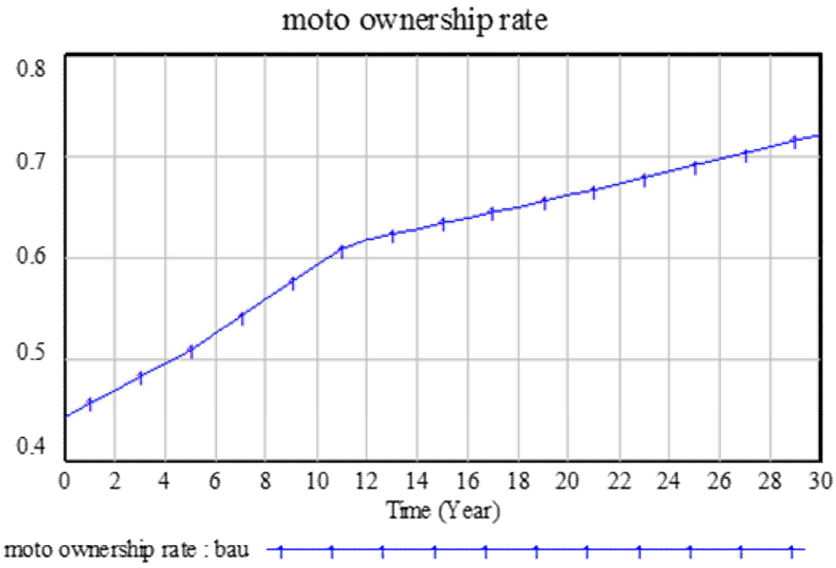


Figure 14 Motorcycle ownership growth in Greater Jakarta

Policy test scenarios

This section gives an overview of the example policies developed for the Jakarta model. It should be noted that these results are not final in that some of the inputs were based around our best estimates and so we suggest that the results should be viewed with this in mind. The next section gives an overview of all policies together before going into a little more detail for each in turn with the animap feature.

Modal shares

We now give an overview of the modal shares computed in terms of daily trips (Table 5) by the following scenarios for the year 2040:

BAU – business as usual
MRT – Jakarta Metro both North-South and East-West lines
MRT + LRT – Jakarta Metro together with light rail integrated with commuter rail
MRT + LRT + toll roads – Jakarta Metro, LRT and toll roads

Table 5: Modal shares by person trips

	Year 2010		Year 2040 BAU		Year 2040 MRT		Year 2040 MRT, LRT		Year 2040 MRT, LRT, Toll Roads	
Mode	Trips, Million	Share %	Trips, Million	Share %	Trips, Million	Share %	Trips, Million	Share %	Trips, Million	Share %
Pedestrian	23.5	22%	24.7	19%	24.5	19%	22.3	17%	22.5	17%
Bus	14.5	13%	15.0	12%	14.8	11%	13.4	10%	13.8	10%
Rail (+LRT)	3.6	3%	3.8	3%	3.7	3%	10.4	8%	10.5	8%
MRT	0.0	0%	0.0	0%	1.0	1%	0.9	1%	0.9	1%
Car	15.2	14%	22.2	17%	22.1	17%	21.3	16%	21.3	16%
Motorcycle	51.1	47%	64.7	50%	64.5	49%	62.3	48%	64.6	48%
Daily Total (Million)	107.9	100%	130.4	100%	130.7	100%	130.5	100%	133.4	100%

Private vehicles including car and motorcycle dominate the modal use with a share of 61% in year 2010 which grows to 67% in the BAU. The growth in private vehicle use could be limited to some extent with the policy initiatives involving public transport infrastructure creation. MRT, LRT scenario presents the best possible scenario with a minimal private vehicle share of 64% in year 2040. Although the toll road scenario presents a similar private vehicle use, in absolute terms, motorcycle trips will be higher by over 2 M trips per day. This is because of the generated traffic due to some trips being cheaper in generalised cost sense due to increased road capacity. Thus in the toll road scenario, total volume of travel is higher by nearly 3 M trips per day. The public transport share of trips (including bus, rail and MRT) on the other hand, drops by a percent from 16% in year 2010 to 15% by year 2040 in BAU. The initiatives on public transport network development certainly generate a positive outcome for the modal use taking the share to about 19% which falls well below the KPI target of 60% use of public transport share. The share of trips by MRT may appear far too little but in absolute terms MRT carries about 900,000 person trips per day which is comparable to similar systems around the world. For example, Delhi Metro Rail which has been in operation for over 10 years now, carried 2.59 M passengers per day in year 2015/6 (DMRC 2016). Given a network length of 212 km of Delhi Metro, the density of travel on an average works out to about 12,200 persons/km. Assuming similar density of travel in Jakarta the ridership estimate works out to about 1.2 M persons per day for 100km of MRT network and the MARS estimate of 0.9-1.0 M persons per day seems to align fairly well with this figure, given that the catchment area is based only on primary affected zones i.e. zones in which stations are located. It should be noted that when MRT and LRT/rail options are improved that this takes riders from the bus and pedestrian shares at a faster rate than from car or motorcycle. This is due to the nature of the choices offered with new public transport options being most attractive to those with no car or moto availability.

Although Table 5 presented the modal shares by person trips, it may be useful to compute the modal use by person-km travelled which takes into account the variability in distances travelled by various modes. Thus as the trips by foot usually tend to be shorter relative to motorised modes of transport, we should see their proportion dropping while the motorised mode share increasing.

Thus the modal shares have been re-computed based on the numbers of users of each mode weighted by the distance travelled. Table 6 shows the passenger-km (pax-km) travelled per year in the base year 2010 and then in year 2040 by scenario as listed earlier. Looking at the base year situation, in year 2010, while 34% of the total travel is by public transport (bus, rail), 65% use private vehicles (car and motorcycle). It is noted that only 1% of travelled distance is performed by foot which clearly takes into account the shorter distance of walk trips. In the future, the BAU situation predicts a reduction in the use of public transport use to 28% losing 6% of travel to private modes taking them up to 71%. The introduction of MRT marginally increases the modal share of public transport, but the introduction of LRT would make travel by public transport more attractive due to its wider network together with integrated facilities to transfer between rail and LRT. Thus when both MRT and LRT are introduced, the public transport share could rise to 36% which is the best estimate of public transport ridership under any scenario.

Thus to improve the ridership further it would be useful to consider integrating MRT and LRT with other forms of public transport (e.g. BRT) and private modes of transport (especially motorcycles) to offer seem-less travel to the residents of Greater Jakarta. Finally looking at the total amount of travel, introduction of new transport systems increases the propensity to travel as some OD costs reduce thus making it attractive to live/work at newer areas which offer affordable housing/business space. MRT+ LRT+ toll roads scenario predicts the highest amount of travel among all with over 218 B pax-km of travel compared to 198 B pax-km by BAU due to the increased efficiency of travelling to areas further afield.

Table 6: Modal shares by passenger-km in Greater Jakarta

	Year 2010 Base		Year 2040 BAU		Year 2040 MRT		Year 2040 MRT + LRT		Year 2040 MRT+ LRT+ Toll Roads	
Mode	Pax-km, Billion	Share %	Pax-km, Billion	Share %	Pax-km, Billion	Share %	Pax-km, Billion	Share %	Pax-km, Billion	Share %
Pedestrian	2.12	1%	2.21	1%	2.20	1%	2.01	1%	2.02	1%
Bus	45.51	28%	45.77	23%	45.35	23%	41.28	20%	42.80	20%
Rail (+LRT)	9.09	6%	10.26	5%	10.09	5%	31.81	15%	32.09	15%
MRT	0.00	0%	0.00	0%	1.61	1%	1.41	1%	1.42	1%
Car	16.36	10%	29.63	15%	29.45	15%	27.65	13%	27.29	13%
Motorcycle	91.20	55%	110.85	56%	110.59	55%	106.06	50%	112.49	52%
Total (Billion)	164.28	100%	198.73	100%	199.29	100%	210.21	100%	218.12	100%

Trip time by various modes

Figures 15-19 illustrate the distribution of trip times during peak period by various modes of travel in Grater Jakarta in year 2040. The travel times are weighted by the number of trip makers and the resulting average travel times by various modes of travel during peak are shown in Table 7. Note that the travel times in Table 7 are door to door and include access/egress times. It is anticipated that average travel time by bus will be just over 100 min in year 2040 indicating the significance of bus as a mode of transport in Greater Jakarta even after constructing the new high capacity mass transport systems such as MRT complemented by the commuter rail together with well integrated LRT system. The average door to door travel time by Jakarta Metro will be about 30 min due to its relatively low outreach especially along the North-South corridor, however that by rail including LRT will be about 47 min due to its spread over a larger geographical area of Greater Jakarta. Finally residents of Greater Jakarta continue to rely on private modes of transport for their commuting/non-commuting needs though with an average travel time of 67 min. Compared to the KPI of maximum travel time of 90 minutes of peak travel time, it appears that many journeys in Jakarta will be well over the target indicating the need to consider improving the overall efficiency of transport systems and land use reallocation where possible.

Figure 15 Peak travel time distribution by bus

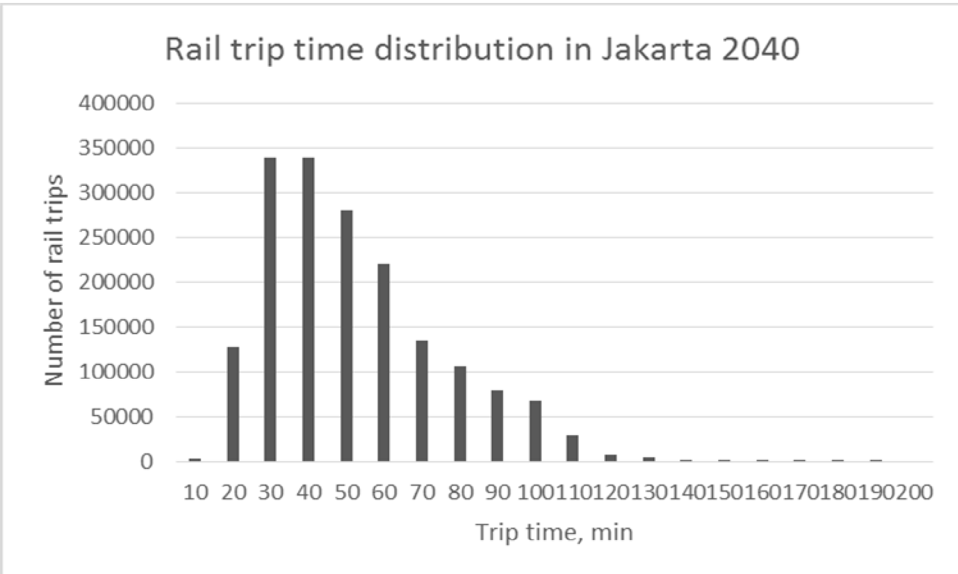


Figure 16 Peak travel time distribution by rail

Figure 17 Peak travel time distribution by MRT

Figure 18 Peak travel time distribution by car

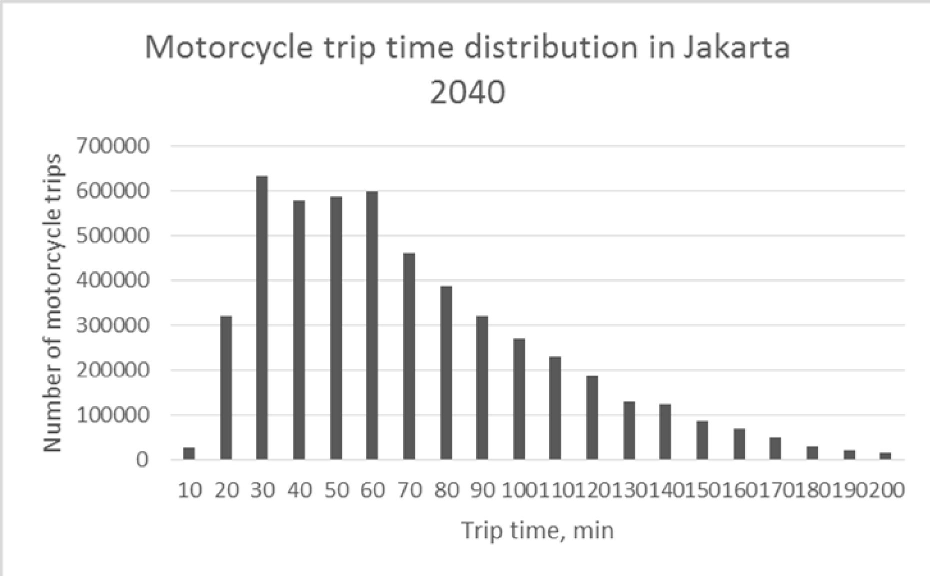


Figure 19 Peak travel time distribution by motorcycle

Table 7: Average peak travel time, min

Mode	Time, min
Bus	103
Rail (+LRT)	47
MRT	30
Car	67
Motorcycle	67

More detailed outputs

This section describes the results of each of the policy scenarios in detail considering the following:

- Growth in modal shares at origin
- CO2 emissions

While looking at the growth in modal shares we have obtained the snapshots of year on year growth in modal shares at year 10, year 20 and year 30 by rail and motorcycles which are possibly the most significant modes in Jakarta. Rail is included as LRT is considered integral to the existing commuter rail which provides extensive connectivity. Besides adding a new network of about 170 km of LRT, the commuter rail is being extended to various destinations including Soekarno Hatta International Airport. Undoubtedly motorcycle is the most dominant of all the modes of transport in Jakarta which deserves a special attention too. However, for the CO2 emissions we have a continuous profile over the modelled period from year 0 year 30. Finally, modal share at origin by MRT is also shown for the three scenarios where relevant (i.e. except BAU).

BAU – business as usual

Figure 20 shows the growth in modal share by rail (including LRT) at the top and motorcycles at the bottom at year 10, year 20 and year 30. The blue colour indicates a drop in modal share while the red colour indicates a gain. From the snapshots, it is clear that rail modal share keeps dropping year on year by up to 15% and the trend continues steadily through time too though the relative drop in share reduces to about 6% by year 30. On the other hand motorcycle share steadily grows which is confined to a smaller number of zones in year 10 which is widespread all over Greater Jakarta by year 30. This indicates that residents of Greater Jakarta will tend to rely on private modes of transport if no policy initiatives have been taken. This will have a significant impact on emissions too. By year 30 (2040) Jakarta will have a total CO_2 emissions of 27.5 Million Tonnes per year from all modes of transport system which is up from about 21 Million Tonnes in year 2010, i.e. a growth of about 31% over the base year (Figure 21). Although this scenario may seem unrealistic as many new initiatives are already in place, it serves as a benchmark to compare the effectiveness of the new policies.

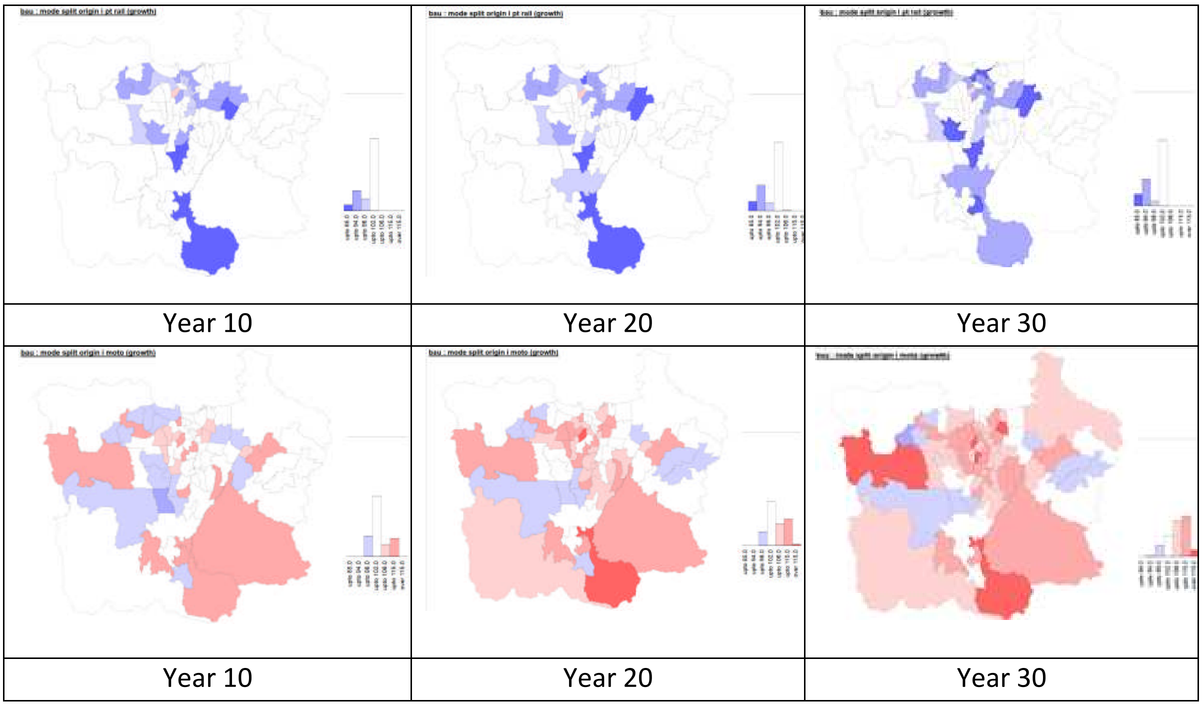


Figure 20 BAU – growth in modal shares at origin rail (top) and motorcycle (bottom)

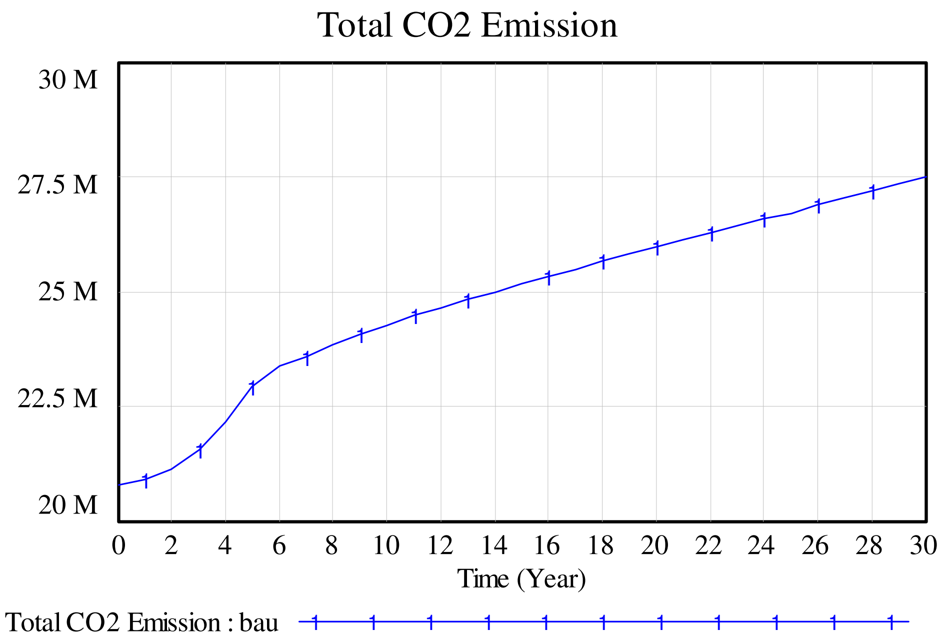


Figure 21 BAU – total CO2 emissions in Million tonnes per year

MRT – Jakarta Metro both North-South and East-West lines

Figure 22 presents the snapshots of origin modal share by MRT at years 10, 20 and 30. In year 10, only the North-South line will be available between Lebak Bulus (zones 1,3) and Kampung Bandan (zone 41) and zone 3 has the highest modal share of 5.7% while all other zones along the corridor have a share of up to 5%. By year 20, the East-West line is also expected to be available which increases the spread of the network and hence the modal shares. Although at an aggregate level the modal share seems too small some zones along the MRT corridor will experience a fairly good proportion of trip makers using the MRT. For example zone 42 will have a share of 10.6% while a few other zones e.g. 21, 22, 24, 28, 31 all have a share of 7-9%. By year 30, the modal shares stabilise at about 8-9% in a majority of the zones. It is noted that some of the trips by MRT have shifted from other forms of public transport such as BRT, regular bus and a few others from motorcycles. The interplay between the public transport modes is not uncommon as the travellers may not have a choice of mode and are captive to use public transport.

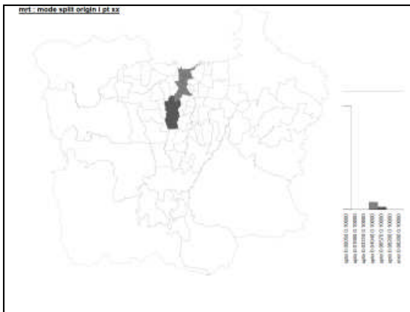
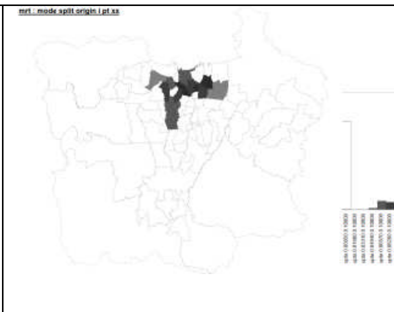
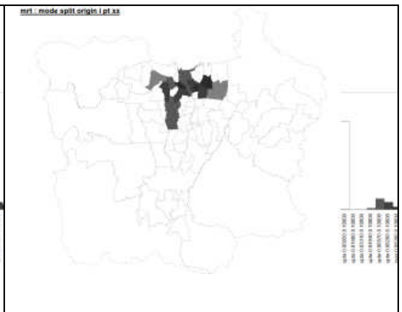
		
Year 10	Year 20	Year 30

Figure 22 Modal share at origin by MRT

Figure 23 shows the growth in modal shares by rail (top) and motorcycle (bottom) for the scenario involving MRT development. The trend in losing modal by rail and increasing modal share by motorcycle continues as with the BAU. However, some zones (e.g. zone 60: Cininong) seem to gain in rail share though for a brief period of time around year 10 but then they also start losing the share by rail thereafter through to year 30. This happens because of the relative change in attractiveness of using different modes of travel through time. Motorcycle continues to gain in its share similar to the BAU though the intensity of reduction in shares has dropped in comparison to BAU. However as the spread of MRT network is limited to about 23km in North-South direction and the longer East-West link is not expected to be available until about year 2024/5, the result seem plausible. In terms of CO2 emissions, the MRT scenario predicts in a marginal drop in total CO2 emissions to 27.4 Million Tonnes in year 30 (Figure 24).

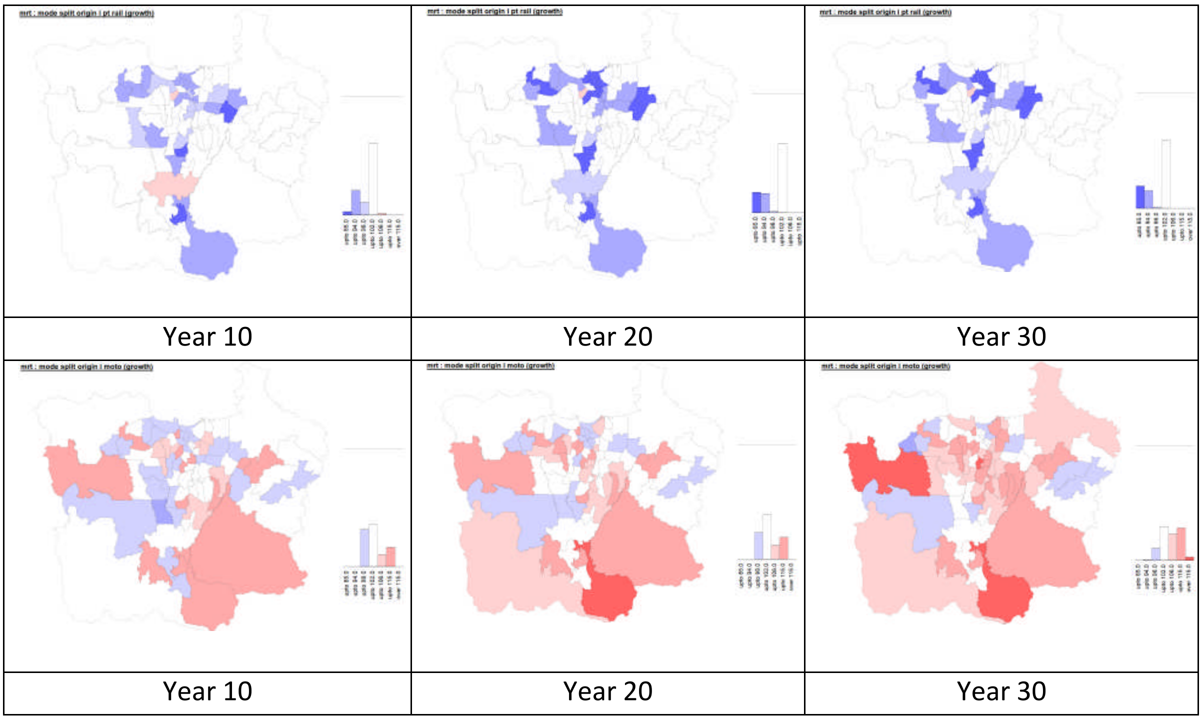


Figure 23 MRT – growth in modal shares at origin rail (top) and motorcycle (bottom)

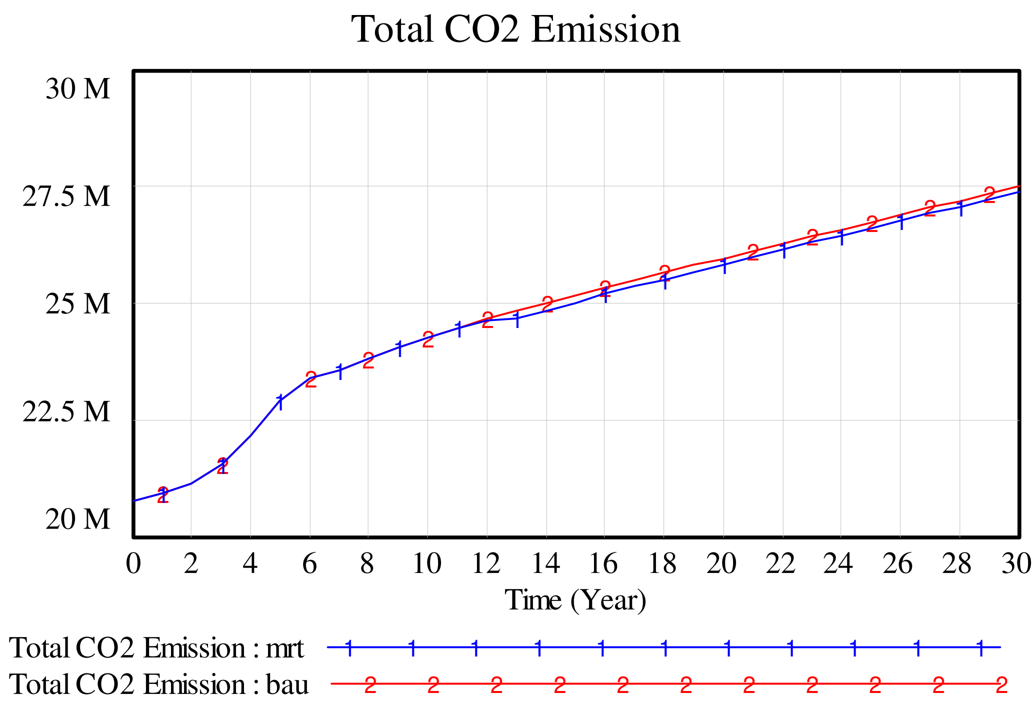
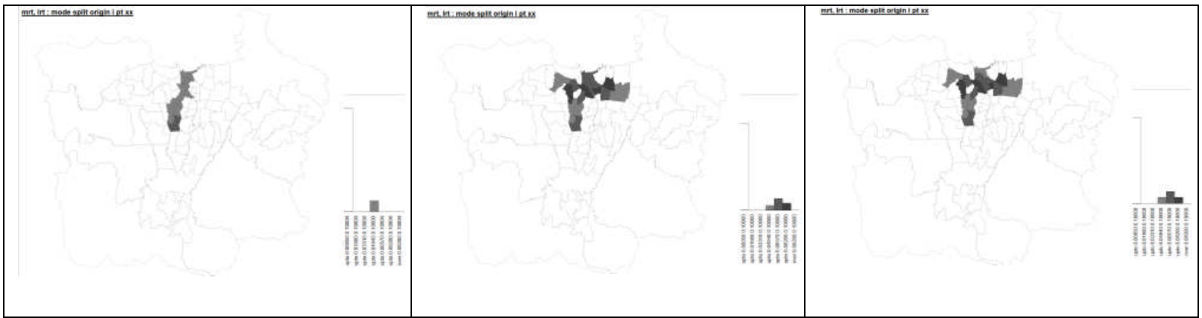


Figure 24 MRT – total CO2 emissions in Million tonnes per year

MRT + LRT – Jakarta Metro together with light rail integrated with commuter rail

Figure 25 shows the modal share by MRT and as the new mode of LRT is introduced, some of the trips from MRT will be diverted to LRT thus reducing the modal shares. For example, zone 3 which has the highest modal share of 5.7% in year 10 with MRT alone, will get pushed down marginally to 5.6%. All other zones along MRT corridor will have a modal share below 5%. Similarly by year 20, zone 42 which had a share of 10.6% will now be 7.5% and other zones 21, 22, 24, 28, 31 will have a share down to 7% and the trend continues to year 30. Thus the two modes of MRT and LRT need to be integrated with each other to complement the service provision than to compete with each other.



Year 10	Year 20	Year 30

Figure 25 Modal share at origin by MRT

Figure 26 presents a contrast both in terms of rail and motorcycle modal shares compared to the earlier scenarios. In particular, the modal share by rail grows in almost all zones along the network of commuter rail together with its extensions and of course the new LRT. For example zones 5, 6, 8, 10, 16, 17, 18, 20 among others have increased their share to over 15% by rail. This has been possible as the new LRT will be highly integrated with commuter rail i.e. stations located next to each other together with some integration in terms of fare too. Looking at the total share of public transport including rail, MRT and bus a few zones viz., 19, 22, 42 have an aggregate of about 40% and a few other zones viz., 21, 23, 24, 25 have shares between 36-39% indicating that public transport demand keeps shifting between new modes and existing modes but it is extremely difficult to get them out of car/motorcycles.

On the other hand, motorcycle loses to rail in many of the zones of Greater Jakarta owing to efficient public transport system being made available. For example in year 10, zones 1, 4, 9, 15 in central Jakarta and zones 65, 67 in the south have registered a drop of over 15% in motorcycle share. At an aggregate level of mode share analysis significant changes to individual zones may not be apparent. However, these will be clearer only at the individual zones and animap facility in MARS is very useful in bringing them out. Thus this analysis clearly shows the interplay between rail and motorcycle in Jakarta. Finally as the motorcycle share diminishes, the CO2 emissions too decrease. Figure 27 shows a drop of CO2 emissions from 27.5 Million Tonnes in BAU to 26.5 Million Tonnes i.e. a reduction of 3.4% which helps improving the environment in Jakarta. Thus MRT + LRT scenario presents the best possible outcome for Greater Jakarta both in terms of modal shares and CO2 emissions (though the relative change is still small).

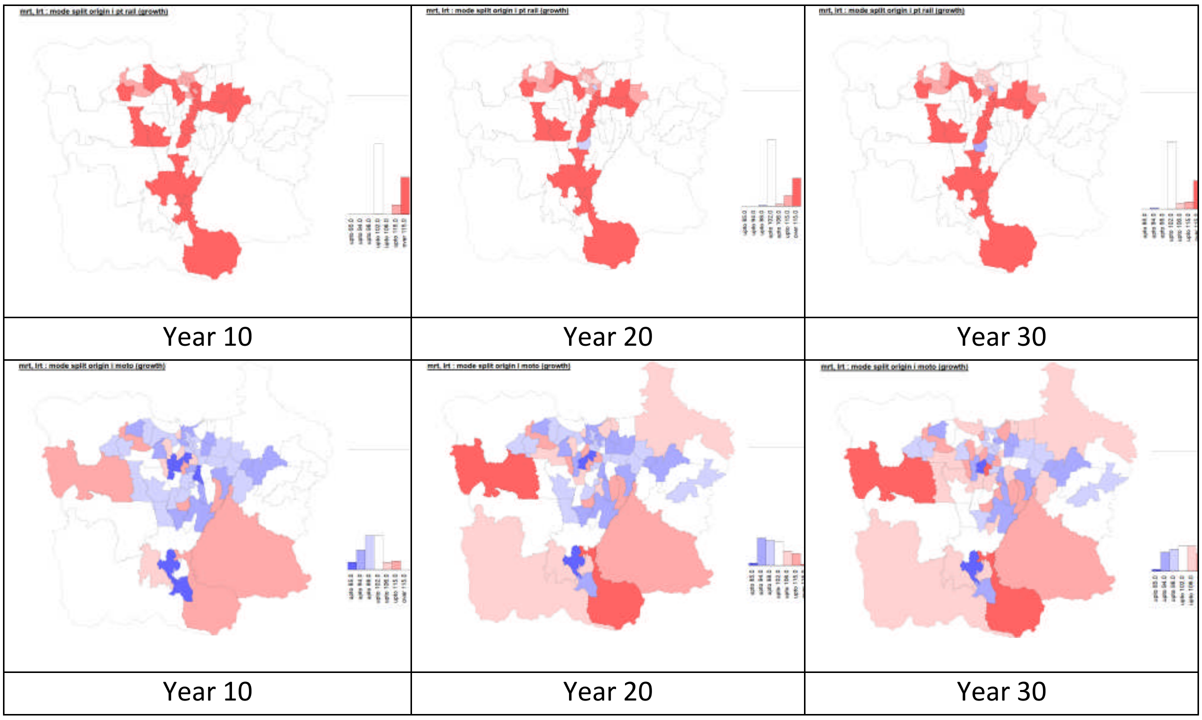


Figure 26 MRT+LRT – growth in modal shares at origin rail (top) and motorcycle (bottom)

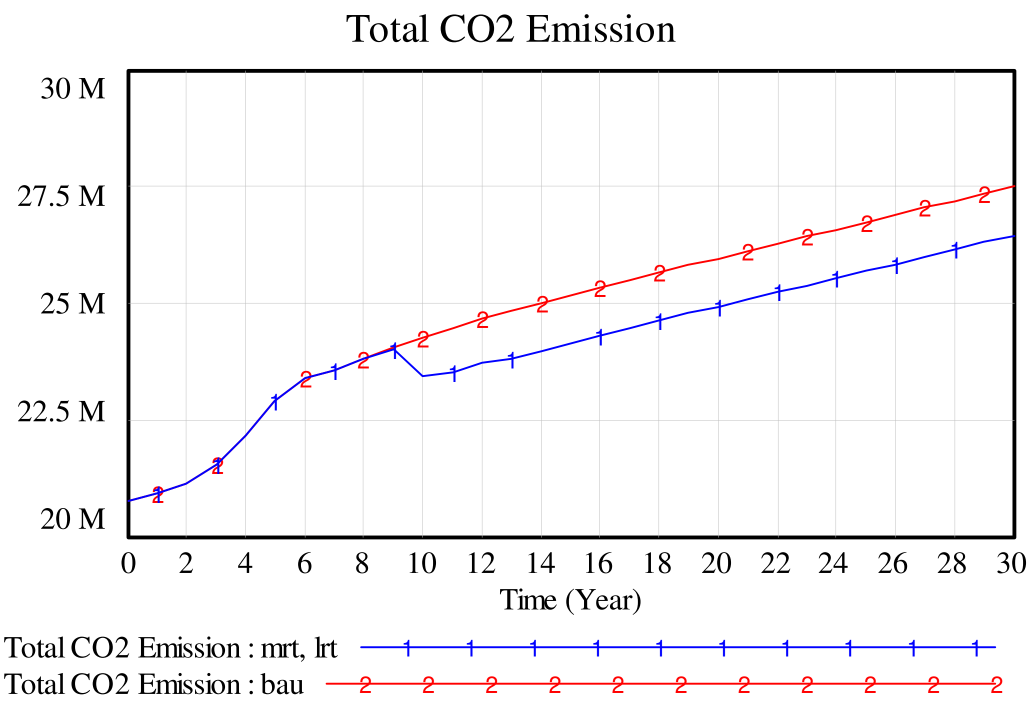


Figure 27 MRT + LRT – total CO2 emissions in Million tonnes per year

MRT + LRT + toll roads – Jakarta Metro, LRT and toll roads

Introduction of toll roads will push the modal shares of MRT further down though only by a slight margin. Figure 28 shows the modals shares of MRT at origin for the scenario that includes MRT, LRT and toll roads. From the snapshots of modal shares, it is clear that the modal shares are at best maintained as that of MRT + LRT scenario and in many cases they drop though marginally. For example zone 3 goes down from 5.7% to 5.5 % in year 10 and all other zones too will drop by a tenth of a percent. Year 20 follows the trend and in year 30, zone 42 will have nearly 3% less trips compared to the MRT alone scenario. All other zones will have a reduced demand for MRT too. Thus in the interest of protecting the investment being made in developing the MRT system it is important that road network expansion is dealt with caution.

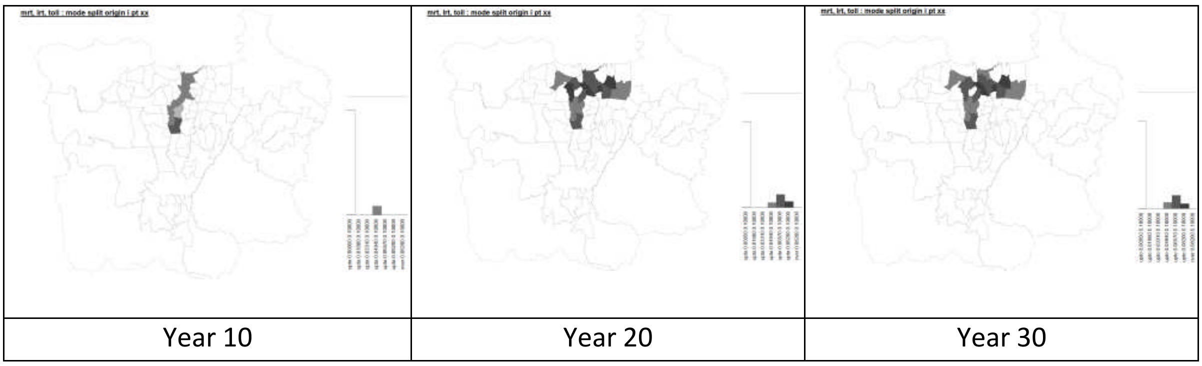


Figure 28 Modal share at origin by MRT

Finally, Figure 29 shows the growth in modal shares by rail (top) and motorcycle (bottom) by a combination scenario which involves developing MRT, LRT and an extensive network of toll roads. The trend in gaining rail modal share continues with the previous scenario of MRT + LRT without toll roads (e.g. zones 5, 6, 8, 10 etc). Similarly motorcycle continues to lose on a year on year basis in many zones located close to the rail network (e.g. zones 1, 4, 9, 15, 65 and 67). However toll roads promote travel by private vehicles due to the 'generated traffic' effect which was described earlier. Thus in some years the total CO2 emissions are much higher than the BAU emissions (Figure 30). For example in year 6 to 9 the total emissions by the scenario are higher compared to the BAU by up to 3.8% per year. But by year 10 the emissions are at or below the BAU emissions until year 30 though by only a small margin. This indicates that the road network expansion as a policy has limitations in itself especially as the additional capacity provided will be taken up so soon and the roads become congested once again. This vicious circle needs to be broken with the help of an effective transport policy.

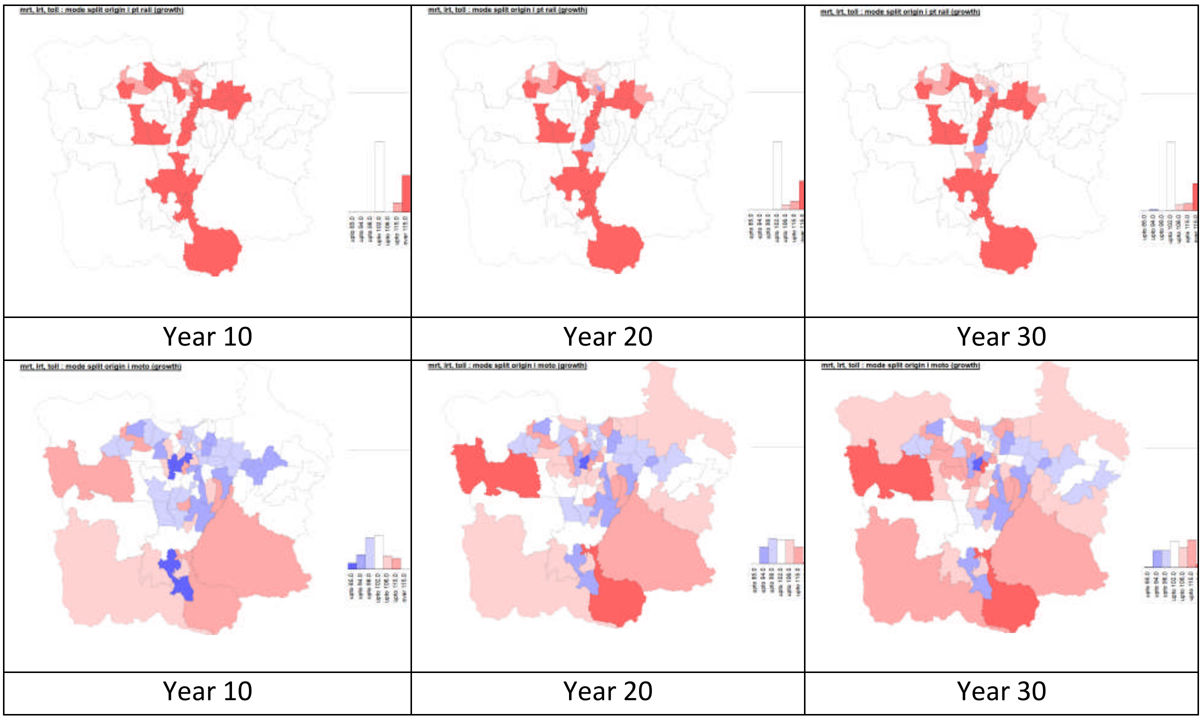


Figure 29 MRT+ LRT+ toll roads – growth in modal shares at origin rail (top) and motorcycle (bottom)

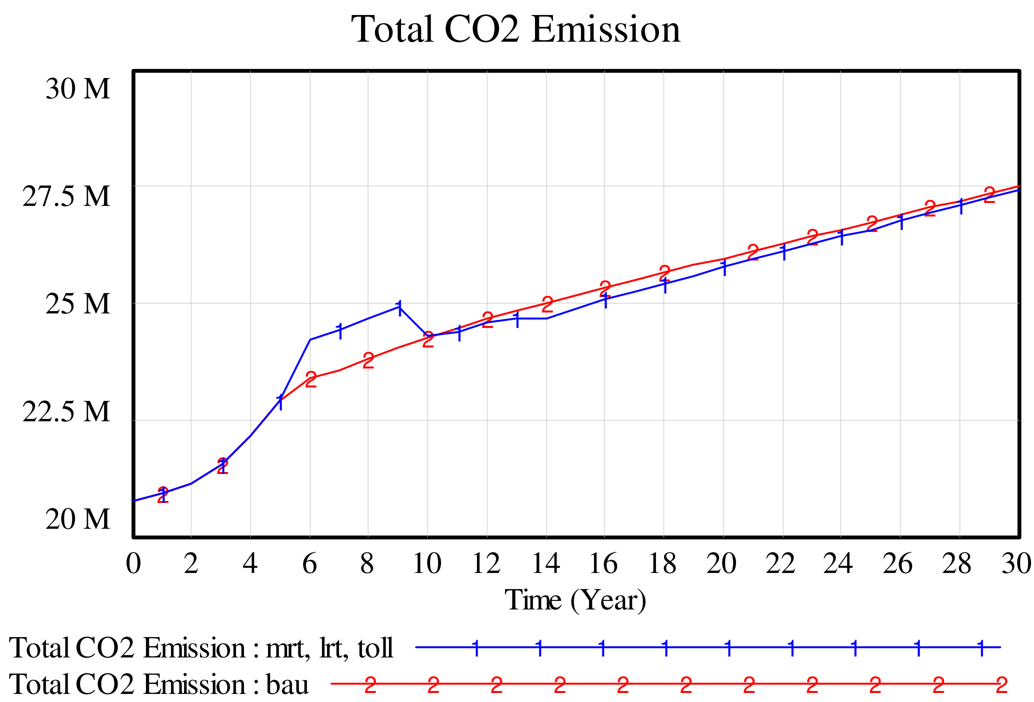


Figure 30 MRT + LRT + toll roads – total CO2 emissions in Million tonnes per year

8 Summary and conclusions

Greater Jakarta is a new administrative area created as a result of the Presidential Decree 103:2015 to deliver integrated, efficient, seem-less travel service to all. Hitherto there were nine different local authorities pursuing their own transport planning objectives with a local perspective, but henceforth they all work together to deliver the Presidential Decree aims. This research project aimed at creating a new land use transport interaction model for Greater Jakarta which helps evaluating the impacts of the public and private transport infrastructure expansion initiatives currently underway thus paving the way for creating Transportation Master Plan for Greater Jakarta. This report forms the final submission and the software model of Jakarta MARS has been handed to GJTA. ITS Leeds have also trained the officers of GJTA to use the MARS model and run/interpret various scenarios/results. This report considered four scenarios as below for illustrating the use of MARS model:

BAU – business as usual
MRT – Jakarta Metro both North-South and East-West lines
MRT + LRT – Jakarta Metro together with light rail integrated with commuter rail
MRT + LRT + toll roads – Jakarta Metro, LRT and toll roads

The main conclusions reached from the analysis of various scenarios are listed below:

- Various policy initiatives involving infrastructure will have varied impacts on the transport system. The combination of MRT, LRT together with commuter rail expansion presents the best possible outcome for Greater Jakarta both in terms of modal shares by public transport and reduced emission levels.

- It should be noted that investment in LRT, MRT and Rail attracts users away from existing BRT, regular bus as well as walking/cycling options. In fact these users are attracted to the new systems more than the car and motorcycle users as they are already captive to use public transport. There is therefore some redistribution of existing public transport users and conversion from walk and cycle to motorised modes.

- Modal share of public transport will improve towards the target of 60% and may reach an aggregate average for entire Greater Jakarta of about 36% at best by year 2040 though some individual zones may experience shares of up to 40%. Although it was not clear whether this target was set based on trips or trip-kilometres, this has a significant policy implication. Public transport demand keeps shifting between new modes and existing modes as the users are captive to use public transport in whatever form that is available. Then the only way to get more people to use the public transport is to limit the ownership of car/motorcycle. Improving the public transport network is costly and the investment being made needs to be protected by appropriate measures to control the growth of private modes.

- In terms of the KPI's Jakarta needs to consider improving the overall efficiency of the system as the travel times will still be well over the targeted average of 90 minutes. It is not clear whether this KPI target was intended to cover the whole of the Greater Jakarta area or just the Jakarta area though – this should be clarified.

- Policy involving road network expansion should be dealt with caution as the emission levels might be higher than the BAU in some years. However, we suggest that motorcycle charges for road use may help to some extent in controlling the generated traffic. This is recommended for future research.

The key to attracting a higher number of trips to public transport is to integrate the new systems with the existing modes of transport. For example, providing affordable parking facilities at train stations is likely to help in a significant manner. Implementing KPI's of increasing the public transport spread to 80% of road length and providing a public transport service within 500 m will help the ease of accessing public transport facilities which have been implicitly addressed in MARS modelling. Integration of public transport modes will hugely help in improving the modal shares as has been illustrated in the case of LRT. Another suggestion would be to consider providing feeder services to MRT/rail network which will improve the overall efficiency and environment too. Other significant policy to improve the modal shares would be to consider managing the ownership of motorcycles. Finally, promoting electric scooters (motorcycles which run on battery) would help in reducing the CO_2 emissions in Jakarta.

9 References

DMRC (2016) Delhi Metro: Annual Report 2015-16, Delhi Metro Rail Corporation Limited, New Delhi, India

Haken, H. (1983). *Advanced Synergetics - Instability Hierarchies of Self-Organizing Systems and Devices*, Springer-Verlag.

Pfaffenbichler, P. (2003). *The strategic, dynamic and integrated urban land use and transport model MARS (Metropolitan Activity Relocation Simulator) - Development, testing and application*, Beiträge zu einer ökologisch und sozial verträglichen Verkehrsplanung Nr. 1/2003, Vienna University of Technology, Vienna.

Pfaffenbichler, P., Emberger, G. and Shepherd, S.P. (2008): The Integrated Dynamic Land Use And Transport Model Mars. *Networks and Spatial Economics* Volume 8 Numbers 2-3 pp 183-200 September (2008).

Pfaffenbichler, P., Emberger, G. and Shepherd, S.P. (2010): A system dynamics approach to land use transport interaction modelling: the strategic model MARS and its application. *System Dynamics Review* vol 26, No 3 (July–September 2010): 262–282

Shepherd, S.P., Pfaffenbichler, P. and Emberger, G. (2007): Improving the capabilities and use of strategic decision making tools. Paper to be presented to the 11th World Conference on Transportation Research, Berkeley, USA 24-28th June 2007.

Sterman, J. D. (2000). *Business Dynamics - Systems Thinking and Modelling for a Complex World*, McGraw-Hill Higher Education.

10 Bibliography

Balijepalli, N.C. and Shepherd, S.P. (2016) Cordon tolls and competition between cities with symmetric and asymmetric interactions, *Transportation,* 43(5), 797-821 http://dx.doi.org/10.1007/s11116-015-9620-3

Balijepalli, N.C., and Shepherd, S.P. (2009): MARS - Optimisation based on strategic appraisal. Report to DfT. September 2009.

Balijepalli, N.C. and Shepherd, S.P. and Rahman, S. (2015) MARS model of West Yorkshire and the use of aggregate models, In *proceedings of the 3rd Conference of Transportation Research Group of India (CTRG),* 17-20 December 2015, Kolkata, India

Koh. A, and Shepherd, S.P. (2009) MARS-SATURN link : Developing a link between MARS and SATURN. Report to DfT September 2009.

Pfaffenbichler, P. and Shepherd, S.P. (2009): MARS – Applying policy instruments to corridors. Report to DfT September 2009.

Shepherd, S.P. and **Balijepalli, N.C.** (2015) A game of two cities: A toll setting game with experimental results, *Transport Policy*, 38, 95-109, http://dx.doi.org/10.1016/j.tranpol.2014.12.002

Shepherd, S.P., Zhang, X., Emberger G., May A.D., Hudson, M., Paulley, N. (2006). Designing optimal urban transport strategies : the role of individual policy instruments and the impact of financial constraints. *Transport Policy Volume 13 Issue 1 pp49-65 January 2006.*

Singh, R. (1999). Improved Speed-Flow relationships: Applications to transportation planning models. 7th TRB Conference on Application of Transport Planning Methods, Boston, Massachusetts.

11 Appendix

11.1 Policies for testing

In the model MARS-Jakarta v3.2 policy instruments for testing can be defined by a combination of sliders in the Vensim® file and data input in the Microsoft Excel® file “Policyfile_v3.2.xls”. Users can navigate from the Vensim® main user interface to the policy definition views by clicking at the items listed in the area framed in red colour in Figure A1.

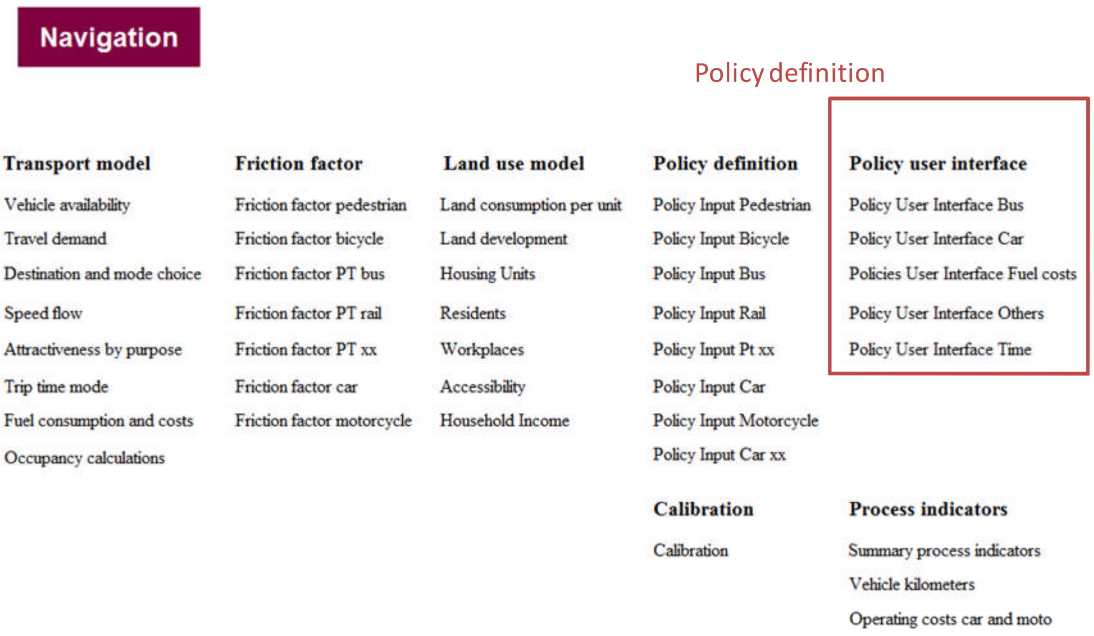


Figure A1: MARS-Jakarta v3.2 Vensim® – main user interface

Assumptions and policies concerning fuel costs can be defined in view “Policies User Interface Fuel costs” (Figure A2). The assumptions affect the whole case study area. Users can define a percentage change for fuel tax and fuel resource costs in two years. The value range for both elements is minus 50 percent to plus 200 percent. Between the two years percentage change is linearly interpolated between the two values. Before the first year percentage change is zero. After the second year the user defined percentage change remains constant until the final year.

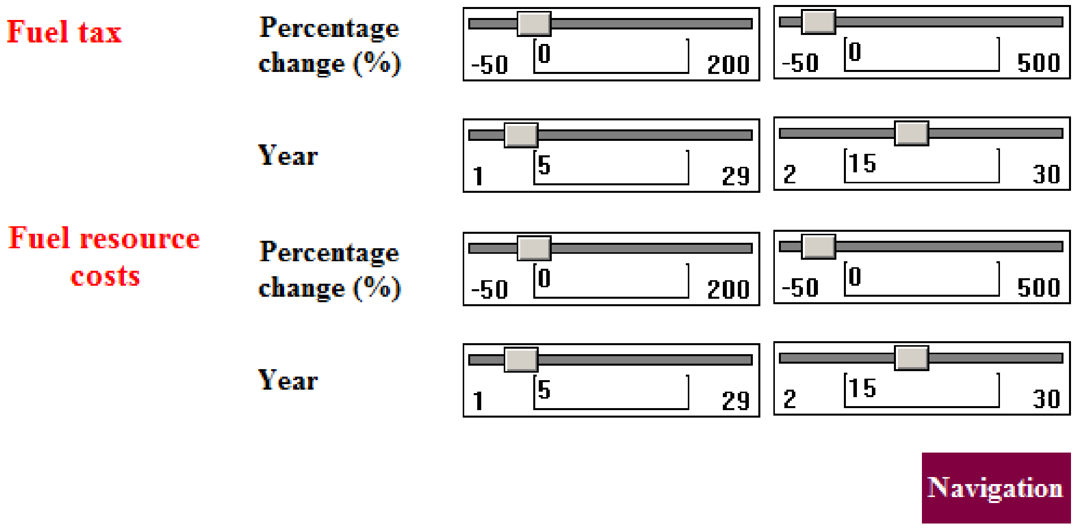


Figure A2: Pre-defined policy instruments fuel costs – Vensim® view "Policies User Interface Fuel costs"

Policies affecting the public mode bus can be defined in view "Policy User Interface Bus" (Figure A3). Users can define a percentage change of bus fares and bus frequency in the peak and off peak period in two years. The value range for these instruments is minus 50 percent to plus 100 percent. Furthermore the user has the possibility to implement a policy bus quality. Bus quality is measured in willingness to pay. The value range for this instrument is minus 20 cent to plus 20 cent. In the Jakarta model 20 cent are equal to 200 IDR. The user has the possibility to define whether these instruments are affecting the whole case study area (uniform) or only a certain corridor. For the latter the corridor has to be defined in the Excel® file "Policyfile_v3.2.xls" (Figure).

Another possibility is to switch the policy bus awareness campaign on or off. Finally the user can implement bus lanes in peak and off peak. The location and extent of bus lanes has to be defined in the Excel® file "Policyfile_v3.2.xls" (Figure A5). For each origin-destination pair the user has to define the percentage of the distance which is driven on separated bus lanes.

The start and end years of all bus related policies can be defined in view "Policy User Interface Time" (Figure A6**Error! Reference source not found.**). Between the two years the values of these instruments are linearly interpolated. Before the first year the value is zero. After the second year the user defined value remains constant until the final year.

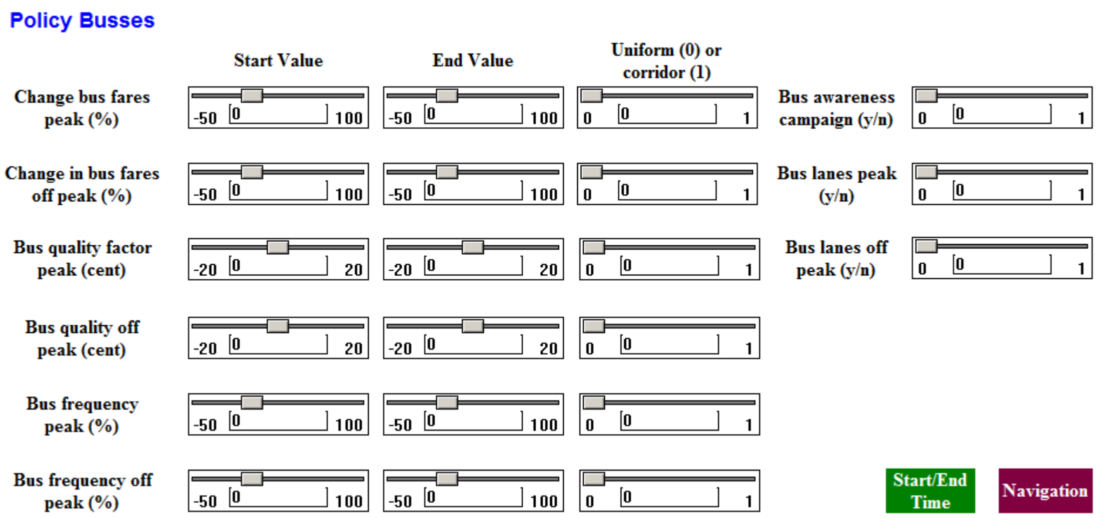
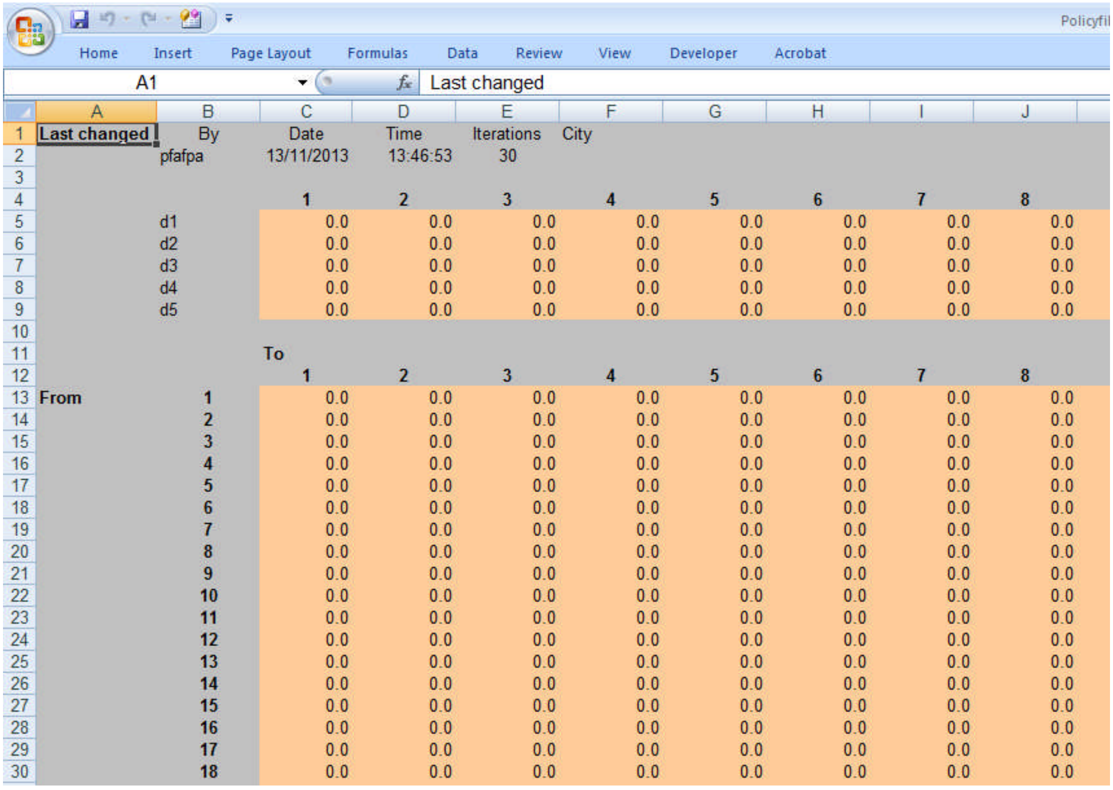
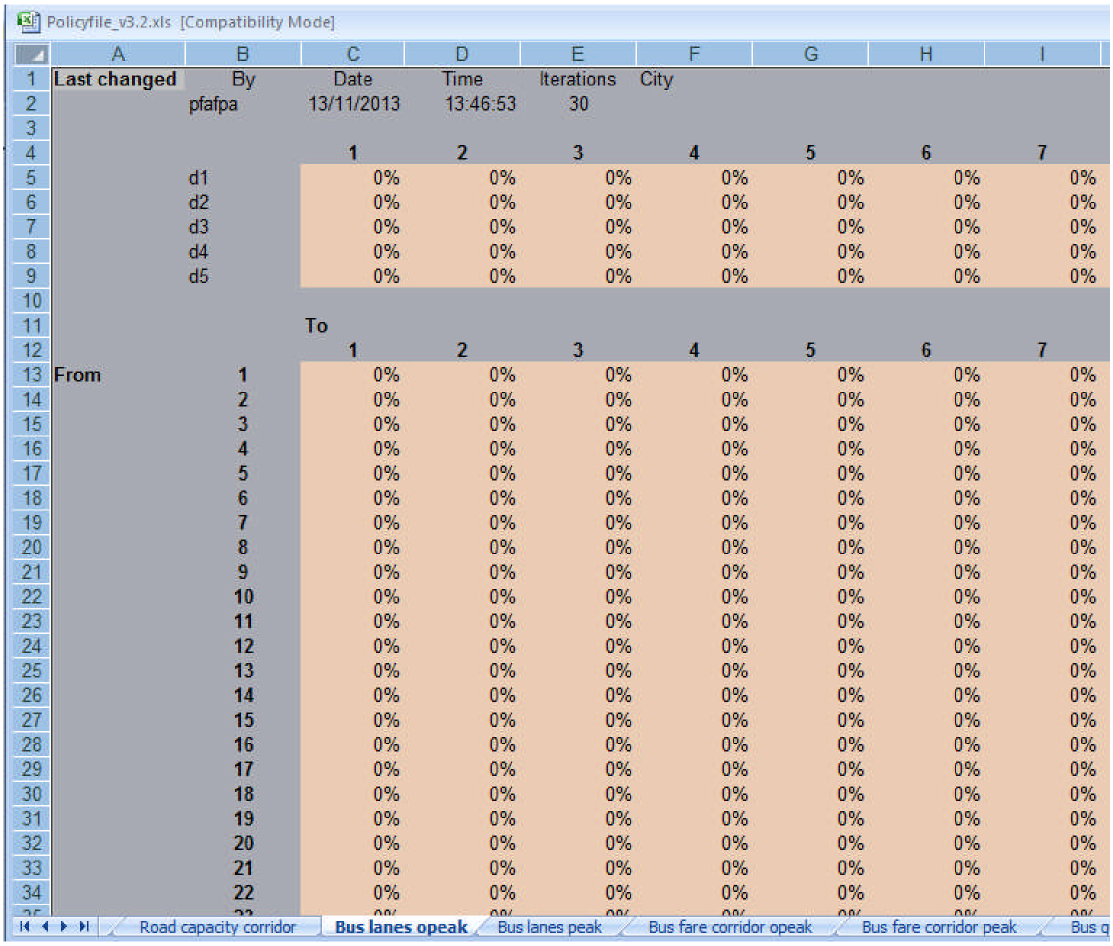


Figure A3: Pre-defined policy instruments mode bus – Vensim® view "Policies User Interface Bus"



	A	B	C	D	E	F	G	H	I	J
1	Last changed	By	Date	Time	Iterations	City				
2		pfafpa	13/11/2013	13:46:53	30					
3										
4			1	2	3	4	5	6	7	8
5		d1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
6		d2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
7		d3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
8		d4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
9		d5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
10										
11			To							
12			1	2	3	4	5	6	7	8
13	From	1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
14		2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
15		3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
16		4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
17		5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
18		6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
19		7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
20		8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
21		9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
22		10	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
23		11	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
24		12	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
25		13	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
26		14	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
27		15	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
28		16	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
29		17	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
30		18	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

Figure A4: Definition of bus policy corridors – fare, frequency and quality



Policyfile_v3.2.xls [Compatibility Mode]

	A	B	C	D	E	F	G	H	I
1	Last changed	By	Date	Time	Iterations	City			
2		pfafpa	13/11/2013	13:46:53	30				
3									
4			1	2	3	4	5	6	7
5		d1	0%	0%	0%	0%	0%	0%	0%
6		d2	0%	0%	0%	0%	0%	0%	0%
7		d3	0%	0%	0%	0%	0%	0%	0%
8		d4	0%	0%	0%	0%	0%	0%	0%
9		d5	0%	0%	0%	0%	0%	0%	0%
10									
11			To						
12			1	2	3	4	5	6	7
13	From	1	0%	0%	0%	0%	0%	0%	0%
14		2	0%	0%	0%	0%	0%	0%	0%
15		3	0%	0%	0%	0%	0%	0%	0%
16		4	0%	0%	0%	0%	0%	0%	0%
17		5	0%	0%	0%	0%	0%	0%	0%
18		6	0%	0%	0%	0%	0%	0%	0%
19		7	0%	0%	0%	0%	0%	0%	0%
20		8	0%	0%	0%	0%	0%	0%	0%
21		9	0%	0%	0%	0%	0%	0%	0%
22		10	0%	0%	0%	0%	0%	0%	0%
23		11	0%	0%	0%	0%	0%	0%	0%
24		12	0%	0%	0%	0%	0%	0%	0%
25		13	0%	0%	0%	0%	0%	0%	0%
26		14	0%	0%	0%	0%	0%	0%	0%
27		15	0%	0%	0%	0%	0%	0%	0%
28		16	0%	0%	0%	0%	0%	0%	0%
29		17	0%	0%	0%	0%	0%	0%	0%
30		18	0%	0%	0%	0%	0%	0%	0%
31		19	0%	0%	0%	0%	0%	0%	0%
32		20	0%	0%	0%	0%	0%	0%	0%
33		21	0%	0%	0%	0%	0%	0%	0%
34		22	0%	0%	0%	0%	0%	0%	0%

Road capacity corridor | Bus lanes opeak | Bus lanes peak | Bus fare corridor opeak | Bus fare corridor peak | Bus q

Figure A5: Definition of bus lanes

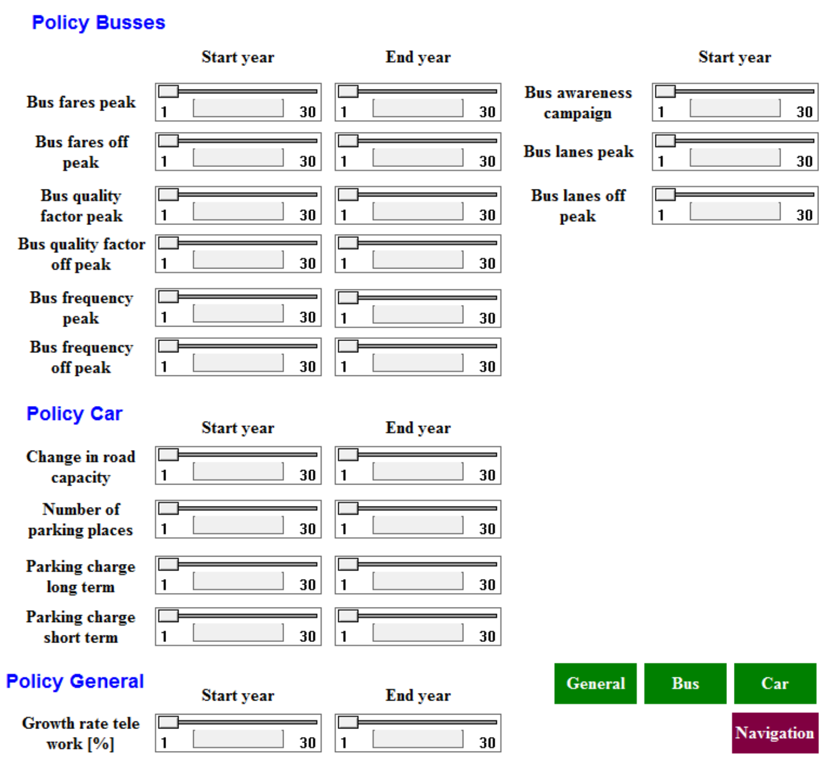


Figure A6: Start and end time of all bus, car and general policies

Policies affecting the mode private car can be defined in view “Policy User Interface Car” (Figure). Users can define a percentage change of road capacity and number of parking places in two years. The value range for road capacity is minus 20 percent to plus 20 percent. The value range for number of parking places is minus 50 percent to plus 100 percent. Furthermore the user can implement additional parking charges for short and long term parking. The value range is 0 to 10 Euros. In the MARS Jakarta model 10 Euros are equivalent to 10,000 IDR. The user has the possibility to define whether these instruments are affecting the whole case study area (uniform) or only a certain corridor. For the latter the corridor has to be defined in the Excel® file “Policyfile_v3.2.xls”.

The start and end years of all car related policies can be defined in view “Policy User Interface Time” (Figure A6**Error! Reference source not found.**). Between the two years the values of these instruments are linearly interpolated. Before the first year the value is zero. After the second year the user defined value remains constant until the final year.

For the policy road charge users have the possibility to define a spatio-temporal phasing in of the instrument. In Vensim® users can turn the policy on and off in peak and off peak (Figure A7). The definition of the spatio-temporal phasing in is defined in the sheets “Cordon charge car peak” and “Cordon charge car off peak” in the file “Policyfile_v3.2.xls” (Figure A8). The origin-destination matrix is organised as a list. Column A contains the zones of origin while column B contains the zones of destination. Clicking on the symbols in cell A4 and B4 opens a filter dialogue. Here users can select single or multiple origin and destination zones to make data input more convenient. Columns C to AG contain the user defined road charge values for the years 0 to 30. Cells with values greater than zero are highlighted in red.

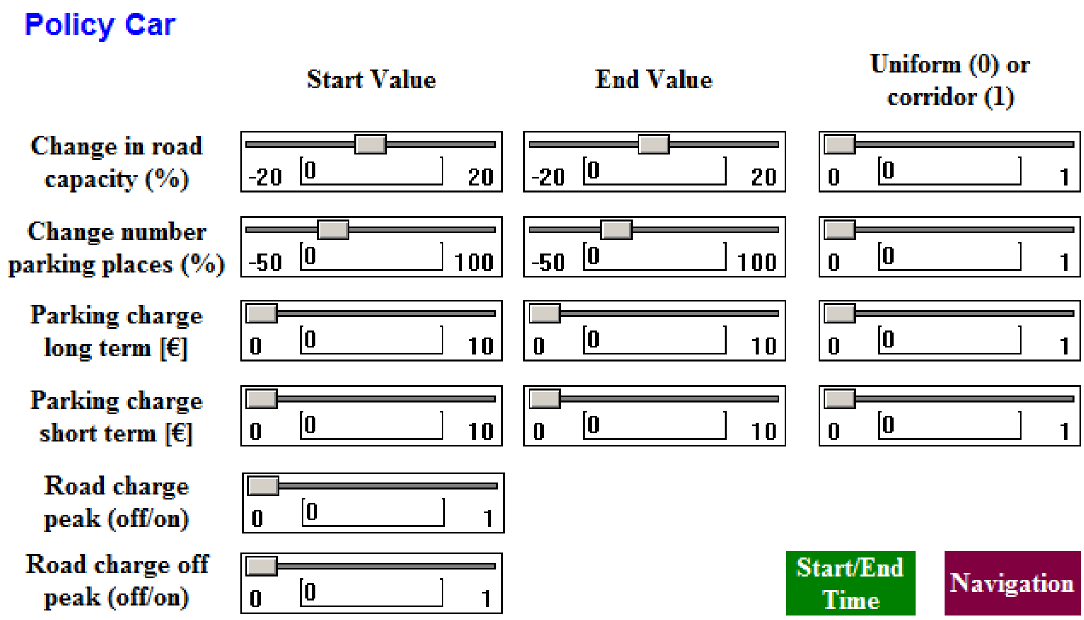


Figure A7: Pre-defined policy instruments mode private car – view “Policy User Interface Car”

Policyfile_v3.2.xls [Compatibility Mode]

	A	B	C	D	E	F	G	H	I	J	K	L	M
1	Cordon charge car peak ('000 IDR)												
2													
3	Source	Destination	Year										
4	MARS_Id	MARS_Id	0	1	2	3	4	5	6	7	8	9	10
5	a1	a1	0	0	0	0	0	0	0	0	0	0	0
6	a1	a2	12	12	12	12	12	12	12	12	12	12	12
7	a1	a3	9.5	9.5	9.5	9.5	9.5	9.5	9.5	9.5	9.5	9.5	9.5
8	a1	a4	0	5	10	15	20	20	20	20	20	20	20
9	a1	a5	0	0	0	0	0	0	0	0	0	0	0
10	a1	a6	0	0	0	0	0	0	0	0	0	0	0
11	a1	a7	0	0	0	0	0	0	0	0	0	0	0
12	a1	a8	9.5	9.5	9.5	9.5	9.5	9.5	9.5	9.5	9.5	9.5	9.5
13	a1	a9	0	0	0	0	0	0	0	0	0	0	0
14	a1	a10	0	0	0	0	0	0	0	0	0	0	0
15	a1	a11	9.5	9.5	9.5	9.5	9.5	9.5	9.5	9.5	9.5	9.5	9.5
16	a1	a12	9.5	9.5	9.5	9.5	9.5	9.5	9.5	9.5	9.5	9.5	9.5
17	a1	a13	9.5	9.5	9.5	9.5	9.5	9.5	9.5	9.5	9.5	9.5	9.5
18	a1	a14	9.5	9.5	9.5	9.5	9.5	9.5	9.5	9.5	9.5	9.5	9.5
19	a1	a15	9.5	9.5	9.5	9.5	9.5	9.5	9.5	9.5	9.5	9.5	9.5
20	a1	a16	0	0	0	0	0	0	0	0	0	0	0
21	a1	a17	9	9	9	9	9	9	9	9	9	9	9
22	a1	a18	0	0	0	0	0	0	0	0	0	0	0
23	a1	a19	0	0	0	0	0	0	0	0	0	0	0
24	a1	a20	18.5	18.5	18.5	18.5	18.5	18.5	18.5	18.5	18.5	18.5	18.5
25	a1	a21	0	0	0	0	0	0	0	0	0	0	0
26	a1	a22	0	0	0	0	0	0	0	0	0	0	0
27	a1	a23	0	0	0	0	0	0	0	0	0	0	0
28	a1	a24	0	0	0	0	0	0	0	0	0	0	0
29	a1	a25	0	0	0	0	0	0	0	0	0	0	0
30	a1	a26	0	0	0	0	0	0	0	0	0	0	0
31	a1	a27	0	0	0	0	0	0	0	0	0	0	0
32	a1	a28	0	0	0	0	0	0	0	0	0	0	0
33	a1	a29	8.5	8.5	8.5	8.5	8.5	8.5	8.5	8.5	8.5	8.5	8.5
34	a1	a30	8.5	8.5	8.5	8.5	8.5	8.5	8.5	8.5	8.5	8.5	8.5

Cordon charge car off peak | **Cordon charge car peak** | Cordon charge moto off peak | Cordon charge moto pea

Figure A8: Spatio-temporal definition of the phasing in of the instrument car road charges – file "Policyfile_v3.2.xls"

Policies affecting other modes than bus and private car can be defined in view "Policy User Interface Others" (Figure A9). Users can define road charges for motorcycles in a similar way than road charges for cars (see above). Furthermore the users can phase in rail lines and Mass Rapid Transit. The principle is the same as with car and motorcycle road charges except that the data input is a binary variable 1/0, i.e. a connection exists or not.

Finally users can implement an area wide policy tele work. The policy is defined as a percentage of commuting trips. The value range is 0 to 5 percent.

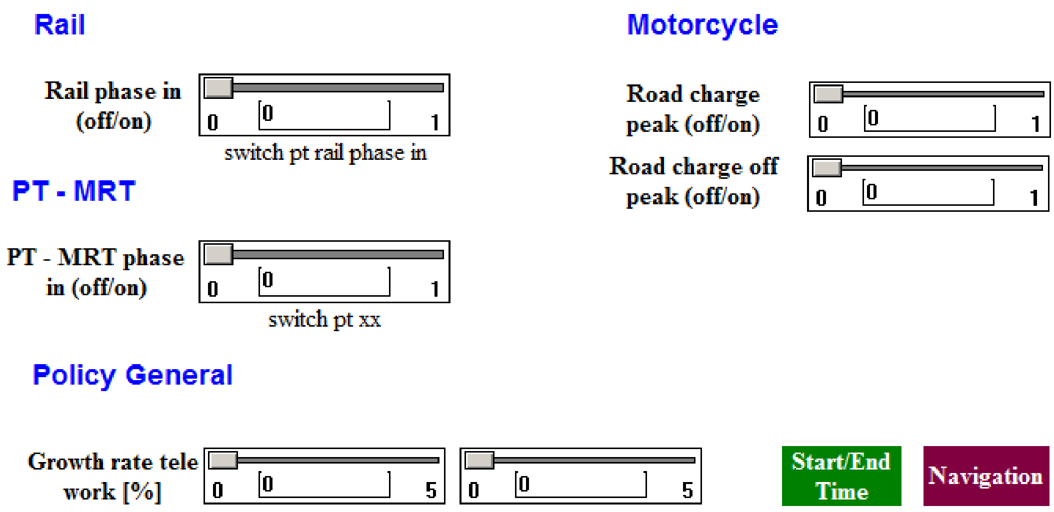


Figure A9: Pre-defined policy instruments others – view “Policy User Interface Others”