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Health co-benefits in mortality avoidance from implementation of the mass rapid transit (MRT) system in Kuala Lumpur, Malaysia

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Abstract

Introduction: The mass rapid transit (MRT) is the largest transport infrastructure project under the national key economic area (NKEA) in Malaysia. As urban rail is anticipated to be the future spine of public transport network in the Greater Kuala Lumpur city, it is important to mainstream climate change mitigation and public health benefits in the local transport development. This study quantifies the health co-benefits in terms of mortality among the urbanites when the first line of the 150 km MRT system in Kuala Lumpur commences by 2017.
Method: Using comparative health risk assessment, we estimated the potential health co-benefits from the establishment of the MRT system. We estimated the reduced CO_2 emissions and air pollution (PM2.5) exposure reduction among the general population from the reduced use of motorized vehicles. Mortality avoided from traffic incidents involving motorcycles and passenger cars, and from increased physical activity from walking while using the MRT system was also estimated.
Results: A total of 363,130 tonnes of CO_2 emissions could be reduced annually from the modal shift from cars and motorcycles to the MRT system. Atmospheric PM2.5 concentration could be reduced 0.61 μg/m^3 annually (2%). This could avoid a total of 12 deaths, mostly from cardiorespiratory diseases among the city residents. For traffic injuries, 37 deaths could be avoided annually from motorcycle and passenger cars accidents especially among the younger age categories (aged 15–30). One additional death was attributed to pedestrian walking. The additional daily physical activity to access the MRT system could avoid 21 deaths among its riders. Most of the mortality avoided comes from cardiovascular diseases. Overall, a total of 70 deaths could be avoided annually among both the general population and the MRT users in the city.
Conclusion: The implementation of the MRT system in Greater Kuala Lumpur could bring substantial health co-benefits to both the general population and the MRT users mainly from the avoidance of mortality from traffic injuries.

Keywords: air pollution; CO_2 emissions; public transport; urban health.

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Introduction

Co-benefits is defined as the "positive effects that a policy or measure aimed at one objective might have on other objectives, …, also referred to as ancillary benefits" (1). From the perspective of Asian developing countries, the concept of co-benefits is important as a bridging tool to environmental and development issues (2). In order to optimize use of the scarce available resources, mainstreaming co-benefits into the early planning and development stage is fundamental (3). Transportation related health co-benefits is often neglected in the evaluation of conventional policies (4). Analysis studies in recent years on alternative transport adoption such as active transports (walking and cycling) (5) and public transits (6) have shown potential positive health impacts on the population.

As a developing nation, Malaysia is not required to reduce carbon emissions quantitatively under the Kyoto Protocol. However, Malaysia has committed to voluntarily reduce 40% of carbon emissions intensity of its gross domestic product (GDP) by 2020 from the 2005 level. Compared to other countries in South East Asia, Malaysia is third highest in total emissions, behind Indonesia and

Thailand (7). The transportation sector has the highest final energy demand (40.6%) and is accountable for 21% of carbon emission in Malaysia (8). With the rapid increase of mobility demand in the cities, transport could be the fastest growing energy end-use sector in carbon emissions (9).

Kuala Lumpur is experiencing a massive urban expansion programme. The main suburbs of Kuala Lumpur are now more densely populated than the city center which provides the most job opportunities. It is projected that the population in Greater Kuala Lumpur will reach 10 million people by 2020 from 6.3 million in 2010 (10). As a result of this spillover effect (11) of the population to the city outskirts, severe traffic congestion occurred with 3 million vehicles entering the city daily (12). Most (70%) of the traffic on the roads during the morning peak hours are single occupancy vehicles (SOV) (13). These situations call for the urgent need for a reform of the transportation system in Kuala Lumpur.

Compared to neighboring Asian countries, Malaysia has a relatively low rate of public transport usage (14). The modal share of public transport has reduced considerably from 34% in 1985 to 10%–12% in 2008 (15). Therefore, the Malaysian government aspires to increase public transport modal share to 40% in 2030 by extending the rail network from the current 15 km to 34 km per million population in 2030 (10). The Klang Valley Mass Rapid Transit (KV MRT) is the entry point project under the National Key Economic Area (NKEA) of Greater Kuala Lumpur. It is the largest infrastructure project investment by the Malaysian Government, costing RM80 billion (approximately 18 billion USD) for the three proposed MRT alignments of 150 km (16). The construction of the first MRT line (MRT 1) from Sungai Buloh to Kajang started in 2011 and is expected to commence operation by 2017. With the rail length of 51 km and 31 stations, it is estimated to serve 1.2 million people with a daily ridership of 400,000 passengers.

The MRT in Kuala Lumpur is a mega infrastructure project with the second and third lines of the system under planning. This paper presents the preliminary findings of health co-benefits assessment in terms of mortality avoidance which will result from the implementation of the first MRT infrastructure in Kuala Lumpur.

Methodology

To estimate the number of deaths that could be avoided with MRT 1, we used comparative health risk assessment [Equation 1] based on the integrated transport and health impact modelling tool (ITHIM) by Woodcock et al. (5) for air pollution and physical activity. The population attributable fraction (PAF) is obtained by comparing baseline exposure without MRT 1 (P(x)) to the future exposure with MRT 1 (Q(x)) using the relative risks at each exposure level (R(x)).

$$PAF=\frac{\int_{x_{min}}^{x_{max}} R(x)P(x)dx-\int_{x_{min}}^{x_{max}} R(x)Q(x)dx}{\int_{x_{min}}^{x_{max}} R(x)P(x)dx} \quad [1]$$

For emissions, we calculated the amount of carbon dioxide and fine particulate matter (PM2.5) emissions that could be avoided using the projected ridership, modal shift, vehicle occupancy and vehicle distance travelled per day by transport mode. It was assumed that in relation to ridership, there would be 66% previous car users and 33% previous motorcycle users. Projected ridership and percentage modal shifts were obtained from the approved Environmental Impact Assessment (EIA) report (2011) of MRT 1; vehicle occupancy from GEF (17); and vehicle distance from the Malaysian Institute of Road Safety Research (MIROS). We used CO_2 emission factors from Bangkok (18) while others were from local testing of vehicles by mode (19). For PM2.5, we also included emissions from tyre wear, brake wear and road abrasion using emission factors from Walker (20).

From the amount of emissions avoided, we calculated the exposure of PM2.5 concentration that could be reduced by using intake fractions (iF) predicted for Kuala Lumpur (21). We also calculated secondary PM2.5 concentration formed from NOx and SOx using iFs from Humbert et al. (22). Relative risks for air pollution were based on the linear dose-response relationship by Ostro (23). Based on a meta-analysis by Zhou and Levy (24), the impact of particulate matter could be expanded spatially by 100–400 m from the mobile source. Therefore, we estimated the population exposed at 1.2 million within 1 km from the MRT alignment using the online software Population Explorer. This is because the MRT is built above or below major roads or highways to reduce construction impacts on existing residential areas. We also used a PM2.5: PM10 ratio of 0.6 in estimating PM2.5 concentration at baseline concentration.

For physical activity, we assumed an estimate of 15 min walk per day from accessing the MRT stations among the MRT users. Baseline physical activity level across age group and gender was taken from National Health and Morbidity Survey 2006. Physical activity was measured in metabolic equivalents (MET). Additional

METs from walking was calculated using 3.3 METs/min from the Compendium of Physical Activity (25). Relative risks were based on disease specific systematic reviews and meta-analyses of case studies and cohorts as collected in ITHIM. We used a curvilinear dose-response relationship by applying exposure transformation factor in ITHIM. For both air pollution and physical activity, we estimated the number of deaths avoided per year using the national disease mortality rates in the Global Burden of Disease Study 2010 (26).

For traffic injuries, we used a simple descriptive approach of three basic dimensions in traffic safety, i.e. exposure, risk and consequences [Equation 2] (27). With the vehicle passenger distances avoided by shifting to MRT, we used the average of 6 years (2007–2012) national data on accident per exposure (km) rate and fatality per accident rate by age obtained from MIROS to calculate the number of absolute deaths avoided.

$$\text{Fatality}=\text{exposure}\times\frac{\text{accident}}{\text{exposure}}\times\frac{\text{fatality}}{\text{accident}} \quad [2]$$

Results and discussion

A total release of 363,130 metric tons of CO_2 per year could be avoided by implementing MRT 1. From this emission, passenger cars would contribute 92.6% and motorcycles 7.4%. Based on the EIA report 2011, the operation of MRT 1 will consume electricity worth 98,459 metric tons of CO_2 per year. This gives a net total of 264,671 metric ton CO_2 avoided per year from the implementation of MRT 1. Removing passenger cars from the road could save a lot more carbon emissions than removing motorcycle.

However, for PM2.5 emissions, modal shift from motorcycles to MRT could avoid 227.87 kg PM2.5 per day which is 62.8% from the total PM2.5 emissions that could be avoided. This was a significant amount considering the smaller percentage of modal shift from motorcycles. Nevertheless, passenger cars emitted most of the NOx and SOx gases which are the precursors to the formation of secondary PM2.5. An amount of 6994.53 kg (95.7%) of NOx and 19.16 kg (84.4%) of SOx per day could be avoided from shifting passenger cars to MRT. Results show that motorcycles played a bigger role in reducing primary particulate matter to the atmosphere while passenger cars were contributing most of the secondary particulate matter. However, the large amount of NOx from passenger cars should not be neglected as it could increase the formation of ground level ozone which is detrimental to health (28).

From the emissions avoided, 0.50 $\mu g/m^3$ primary PM2.5 and 0.11 $\mu g/m^3$ secondary PM2.5 exposure concentration could be reduced. This gave a total reduction of 0.61 $\mu g/m^3$ in PM2.5 exposure concentration among the nearby population. Overall, this is a 2.2% reduction from the current average of 27.45 $\mu g/m^3$ PM2.5 concentration. Most of the PM2.5 concentration avoided came from motorcycle use reduction (0.32 $\mu g/m^3$). According to Rahman et al. (29), motor vehicles contributed 67.6% of fine particle in the Klang Valley. Thus, MRT 1 could reduce 3.3% from the 18.56 $\mu g/m^3$ PM2.5 contributed by traffic in the surrounding area of the MRT 1 alignment.

A total of 70 deaths could be avoided from the implementation of MRT 1 (Table 1). 54.2% and 30.4% of the avoided deaths came from traffic injuries and physical activity among the MRT users. A total of 17.7% of the avoided deaths came from improved air quality among the nearby population. This result is comparable to other studies done on the public transport scenarios (6, 30). The highest number of deaths avoided per year from reduced PM2.5 was from ischaemic heart disease (39.8%) followed by respiratory disease (27.1%). For physical activity, the highest number of deaths avoided was from ischemic heart disease (50.8%) followed by cerebrovascular disease (29.8%).

Most of the deaths avoided for both reduced air pollution and increased physical activity were from cardiovascular diseases because of the high mortality rates in the population. However, percentage reduction indicated that reduced air pollution had the most impact on lung cancer (1.06%) while increased physical activity had the most impact on dementia (16.8%) and diabetes (13.5%). Traffic fatality from motorcycles (51.2%) was higher than that of passenger cars (48.8%) especially among the younger age groups (15–30 years), because of high fatality rates among young people. Pedestrian walking caused a small increase in mortality from the 15 min walk per day to access the stations. Deaths from pedestrian walking are less significant for MRT use because of the short distance of walking. In addition, walking pathway is often accompanied in infrastructure planning of rail station. Although the railway in Kuala Lumpur has experienced several technical breakdowns, no related injuries or deaths have been reported so far.

Limitation

The calculations were based on secondary data obtained from various local departments. Vehicle distance traveled was on daily basis instead of by trip. It was assumed that all the trips in a day by private motorized vehicle were

Table 1: Number of deaths that could be avoided from the implementation of MRT 1 in Kuala Lumpur.

Related diseases (age)	**Number of deaths**		**Reduction**	**% reduction**
	Without MRT 1	**With MRT 1**		
Air pollution (PM2.5)				
Acute respiratory disease (<5)	11.15	11.13	0.02	0.20
Lung cancer (>30)	93.31	92.32	0.99	1.06
Cardio-respiratory disease (>30)	2084.82	2073.34	11.48	0.55
Hypertensive heart disease	51.65	51.37	0.28	
Ischaemic heart disease	902.40	897.43	4.97	
Cerebrovascular disease	479.91	477.28	2.63	
Inflammatory heart disease	46.98	46.72	0.26	
Respiratory disease	615.43	612.04	3.39	
Total			12.49	
Physical activity				
Breast cancer	18.45	17.95	0.50	5.22
Colon cancer	16.02	15.46	0.56	6.88
Dementia	0.85	0.78	0.07	16.82
Depression	0.00	0.00	0.00	0.00
Diabetes	34.70	32.36	2.34	13.50
Cardiovascular disease	305.48	287.53	17.95	0.05
Hypertensive heart disease	12.60	11.92	0.68	10.33
Ischaemic heart disease	179.12	168.23	10.89	9.77
Cerebrovascular disease	113.76	107.38	6.38	10.88
Total			21.42	
Traffic injuries				
Motorcycle	19.57	0.00	19.57	
Passenger cars	18.67	0.00	18.67	
Pedestrian walking	0.00	1.59	−1.59	
Total			36.66	

replaced by using MRT for those who shifted mode. The modal shift from buses to MRT was not taken into account because of its small contribution (1%) and this study focused mainly on private motorized vehicles. Emission factors used were from the JICA report in 1993 (19) which may be outdated but it is the only local source of emission data. In addition, there is no vehicle age limit in Malaysia. Air quality exposures in the transport microenvironments were not accounted for. Also, we used physical activity level from leisure and occupational domains although relative risks used were obtained mainly from leisure activity related epidemiological studies. The social benefits from using public transport were not quantified due to methodological challenges. Nevertheless, various researches have shown the health benefits of social capital in transport (31).

Conclusion

In summary, the implementation of the MRT system in Kuala Lumpur will improve the level of sustainable transport in the city. Besides contributing to cutting carbon emissions from the transport sector, there will be public health co-benefits generated from the infrastructure. Shifting both motorcycles and passenger cars off the road could abate traffic emissions, improve air quality, reduce traffic injuries and incorporate physical activity into the daily lifestyle of MRT users. The upcoming second and third line of MRT would be expected to provide similar co-benefits.

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