大舜政策研究中心

Dashun Policy Research Centre

Transport, Economic, Social and Environmental Benefits of a New Railway Line

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Project Team: **Ir Dr Raymond Ho Chung-tai**
Chairman, Dashun Policy Research Centre
Ir Gordon Cho Wah-fu
Executive Director, Dashun Policy Research Centre
Ir Dr. H.F. Chan
Managing Director, Cinotech Consultants Ltd.
Dr. K.W. Li
Associate Professor, Department of Economics and Finance, City University of Hong Kong
Raymond Cheng
Environmental Consultant, Cinotech Consultants Ltd.

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1. INTRODUCTION

1.1 At present, MTR is building more and more rail lines, e.g. Shatin-Central Link, the South Island Line, the West Island Line, etc. to facilitate the movement of people in the population centres not previously covered by the MTR lines. It is obvious that a new railway line will result in imputed economic value of travel time saving, benefits of improved road safety, enhanced development potential of the areas the new line served, financial returns to Government from enhanced property values in the new line catchments, not least environmental health benefits.

1.2 Besides, these new lines would take away some passengers from the existing bus and minibus routes and hence would reduce the roadside pollution and improve the overall air quality in Hong Kong.

1.3 On the other hand, bus companies and minibus operators may re-route their buses and minibuses to pick up passengers in areas not served by the new lines or to serve passengers between population centres and the new railway stations. Hence, there may be some re-distribution of the vehicular emissions and the roadside pollution.

1.4 The net environmental benefits of electrifying the transportation system must be calculated over the areas based on a holistic view of the bus and minibus routings.

1.5 Apart from air quality, there may be noise reduction benefits from less vehicles on the road due to the new MTR line and this can make the areas quieter since the MTR cars run mainly underground.

1.6 However, there are other factors which might overshadow the environmental benefits, and must be suitably considered before the net environmental benefits can be ascertained.

1.7 In the past, the environmental benefits from reduction of pollutants emission were estimated in terms of tons of pollutants/year. In order to include the environmental benefits in the capital budgeting process and hence reflect the actual value of building new railway lines, Dashun Policy Research Centre was appointed by MTRC to carry out a study to evaluate the benefits from improvement of air quality and in particular the costs avoidable from reduction of air pollutants from road transport.

2. SCOPE OF STUDY

2.1 Under the Strategic Highway Project Review System (SHPRS), the proposed project shall be assessed in its operational effectiveness, economic effectiveness, financial effectiveness, environmental effectiveness, public acceptance and developmental considerations. According to the SHPRS, the economic effectiveness is evaluated by means of evaluating the Economic Internal Rate of Return (EIRR) of the Project and the environmental costs is assessed in terms of the changes in the quantity of air pollutant emissions.

2.2 As the scale of the Study is immense and there appears to be short of relevant data even if the study is confined to a specific MTR line, it is pragmatic to conduct the Study in several phases. The first phase would be to review the economic gains and the environmental benefits as a result of a new railway line in Hong Kong. Subject to availability of the relevant data from other transport operators or the Transport Department, a case study will be conducted for the Tseung Kwan O line.

2.3 The scope of this Study is as below:

- Review the transport, economic, environmental and social costs and benefits as result of a new railway line in Hong Kong with reference to the Government's Strategic Highway Project Review System (SHPRS),
- Formulation of a scheme for evaluating the net air quality benefits attributable to a new rail line.

3. OVERVIEW OF TRANSPORT, ECONMIC, SOCIAL AND ENVIRONMENTSL COSTS AND BENEFITS

Transport and Economic Benefits

3.1. By opening a new rail line, we anticipate there will be a shift of passengers from road transport to rail transport. This would lead to a reduction in the number of vehicles (buses, private cars, minibuses, taxis, etc.) to be purchased [1].

3.2. New railway lines reduce the number of vehicles operating on the road, which in turn reduce the number of operators (such as bus drivers, maintenance workers) [1].

3.3. New railway lines reduce the demand for new roads, and this would save money for the construction of new roads. New railway lines reduce the demand for carparks and hence save the cost for construction of new carparks [1].

Social Benefits

3.4. Railway lines are fast and reliable, and prevent unpredictable road congestion and accidents. Railway lines help to save passenger time [2].

3.5. Railway lines are a comfortable means of transport. Travelling by railway helps relief tiredness and enhances productivity. Statistics show that commuting fatigue reduces labour productivity. The decline is 1.4% for railway and 7% for buses [3].

3.6. Construction of railway brings direct income to contractors and consultants. After operation, new railway lines help increase regional population. The increase of population with rises of demand boosts the regional economic activities [4].

3.7. New railway lines help achieving the strategic planning of a city. It also enhances urbanization, integration of markets and economies of scale [4].

3.8. Railway is a safer means of transport than roads: implementing new railway lines help reduce traffic accidents [5].

3.9. New railway lines enhance mobility and accessibility to different regions of a city. Elderly are particularly benefitted. Accessibility enhances citizen social inclusion such as career opportunity, social support and participation in activities [6].

Environmental Benefits

3.10. Air pollution is a major environmental concern in Hong Kong. Many studies [7] have found that air pollutants are major risk to cardiovascular and respiratory disease. After 1990, HKSAR gradually restricted the fuel Sulfur content; and this modest regulatory action has led to significant health gains. It is anticipated that implementing a new railway line may help to decrease traffic emission and hence reduce the cost of air pollution related disease [7].

3.11. New railway lines reduce the number of vehicles on the roads and help save fuel consumption in this respect. This would contribute in the long term to improvement of air quality and global climate change [4].

3.12. New railway lines help to reduce traffic noise to roadside residents. Railway trains can be designed to travel underground or on viaduct, where noise control is easier to implement. Railway lines can be located far away from residential areas. Furthermore, trackside noise barriers and partial enclosures are feasible and more cost effective for controlling railway noise than roadside noise barriers [8].

3.13. Road surface causes more serious light pollution because road surfaces are smoother, causing directional reflection of light, while railroad surfaces are rough, causing only diffuse reflection. Furthermore, roads require higher illumination; a large number of street lighting is required to be installed for night visibility. For rail, illumination requirement is lower as trains travel on tracks.

4. FORMULATION OF EVALUATION SCHEME FOR ENVIRONMENTAL BENEFITS

Reduction of traffic emissions

4.1 By introducing a railway line to a town or region, part of the passengers originally commute by road transport will be drawn to the new rail. Assuming a railway line with designed train to carry x passengers, the distance between adjacent station is y km, there will be z trains passing the station in 1 hour and the occupancy rate of the train is n%. Then between two stations:

The passenger mileage by the train = x*n%*z*y …………….. (1)

4.2 By considering all stations, the hourly passenger-mileage of the railway line can be obtained. As the passengers are drawn from road vehicles, we can find out the hourly reduction in vehicle-mileage for each type of road vehicles due to the operation of the new railway line, such as X1 vehicle-km for private cars, X2 vehicle-km for bus etc. Taking the emission factors to be, say, Y1 for private cars, Y2 for bus etc.,

The hourly reduction in emissions = X1*Y1+X2*Y2+X3*Y3… ……. (2)

By considering all the 8760 hours of (24hrs x 365 days) emission reduction, the annual figure can be obtained.

4.3 Taking for example, town A introduces a new railway line with trains designed to carry 300 passengers each trip, and the railway line has a total of 3 stations, i.e. stations S1, S2 and S3. The distance between S1-S2 is 3km and between S2-S3 is 4km. The operating frequency is 12 trains per hour, for the hour 0800-0900, the occupancy rate for train between stations S1-S2 is 80% and that between stations S2-S3 is 90%.

The passenger mileage for the railway line =300*80%*12*3+300*90%*12*4
=21,600 passenger-km.

These passengers are drawn from road vehicles. By studying the shifting of passengers from road vehicles to railway, it was found that for the hour 0800-0900, the reduction in vehicle-mileage of road traffic is shown below in **Table 4.1**:

Table 4.1 Hourly reduction in vehicle mileage of road vehicles due to introduction of new railway line

Vehicle Type	Reduction in Vehicle-Mileage, Vehicle-km
Private Car	6000
Taxi	3000
Light Good Vehicle Cat.3	2000
Light Good Vehicle Cat.4	1500
Light Good Vehicle Cat.6	500
Heavy Good Vehicle Cat.7	1500
Heavy Good Vehicle Cat.8	800
Public Light Bus	1200
Private Van Cat.4	600
Private Van Cat.5	1000
Non-Franchised Bus Cat.6	500
Non-Franchised Bus Cat.7	300
Non-Franchised Bus Cat.8	800
Franchised Bus Single Decker	600
Franchised Bus Double Decker	2500
Motor cycle	1000

4.4 According to EPD's EMFAC2.60 database with condition set at 23^{o}C, 80% relative humidity, 47km/hr traffic speed and non-cool start scenario, the hourly emission factor of Respiratory Suspended Particulates (RSP or PM10) for these vehicle types have been calculated and the results are shown in **Table 4.2**.

Table 4.2 Hourly emission factor for 16 types of vehicles

Vehicle Type	Emission Factor (g/vehicle-km)
Private Car	0.0028
Taxi	0

Light Good Vehicle Cat.3	0.0178
Light Good Vehicle Cat.4	0.0162
Light Good Vehicle Cat.6	0.0294
Heavy Good Vehicle Cat.7	0.0405
Heavy Good Vehicle Cat.8	0.07
Public Light Bus	0.0426
Private Van Cat.4	0.0063
Private Van Cat.5	0.0318
Non-Franchised Bus Cat.6	0.1187
Non-Franchised Bus Cat.7	0.2076
Non-Franchised Bus Cat.8	0.1431
Franchised Bus Single Decker	0.0477
Franchised Bus Double Decker	0.053
Motor cycle	0.005

4.5 By multiplying the vehicle-mileage with the corresponding emission factors, the hourly emission reduction of PM10 is 697.08g (0.697kg). By repeating the process for each hour of a year, the annual reduction is calculated to be 0.697kg x 8760 hours = 6.106 tons.

Increase in pollutants emission due to power generation

4.6 MTRC railway is operated by electricity but generation of electricity consumes fuel and hence emits air pollutants at power plants. Although there are no significant emissions of air pollutants around the railway lines, operation of a new railway line does contribute to certain extent air emissions from the power plant which supplies electricity to MTRC. However, according to the MTRC sustainability report for 2007, the MTR Corporation's annual electricity consumption was 111,442MWh (equivalent to 401.191 tera-Joules) [9]; on the other hand the 2007 annual power generation of Hong Kong was 140,212 tera-Joules [10]. Hence, MTR Corporation only consumed 0.29% of the total electricity in Hong Kong. The increase in operation of a new railway line would be even more negligible. Furthermore, the Environment Protection Department (EPD)'s Air Monitoring Stations at Tuen Mun and Tung Chung show no higher concentrations of pollutants than those measured at other stations. Therefore, it may be concluded that the operation of a new railway line does not contribute significantly to extra pollution from power stations and certainly very little pollution at street level.

Converting the reduction in emission to change in ambient concentration

4.7 Reduction in emission of pollutants into the atmosphere from a town or region will contribute toward decrease in the ambient concentration of the pollutants. Nitrogen Oxide (NOx) and Respiratory Suspended Particulates (RSP or PM10) are the major pollutants of concern for road transport and show the strongest adverse health effects, according to various epidemiological studies [11],[12].

4.8 In order to establish a causal relationship, if any, between the emissions and pollutant concentrations, relevant data from EPD and the literature have been studied. The annual NOx and RSP emissions from road traffic can be obtained from EPD's emission inventory [13] and are tabulated in **Table 4.3** and T**able 4.4**, respectively.

Table 4.3 Annual NOx emissions from road transport

Year	Road Transport Emission - NOx (Tons)
2005	36,000
2006	35,500
2007	35,100
2008	34,600
2009	33,000
2010	32,700
2011	32,700
2012	30,700

Table 4.4 Annual RSP emissions from road transport

Year	Road Transport Emission - RSP (Tons)
2005	2,000
2006	1,840
2007	1,680
2008	1,520
2009	1,360
2010	1,330
2011	1,170
2012	1,200

4.9 The ambient concentrations of NOx and RSP have been extracted from EPD's air quality database [14] for Air Monitoring Stations around Hong Kong. Annual average concentrations from all stations (except the ones at Tap Mun and Tuen Mun) are considered and averaged to represent non-roadside and road-side conditions. Tap Mun Station is excluded because this station is located in rural area and far from road traffic. Tuen Mun Station has also not been included because air quality data are only available since 2014. It should be noted that no records of NOx concentrations are available from air monitoring stations of the Eastern District. The air quality data are presented in **Table 4.5** and **Table 4.6** under non-roadside conditions and in **Table-4.7** and **Table- 4.8** for road side conditions.

Table 4.5 Ambient concentration for NOx for general (non-roadside) stations, measured in $\mu g/m^3$

Year	Central /Western	Kwai Chung	Kwun Tong	Sham Shui Po	Shatin	Tai Po	Tsuen Wan	Yuen Long	Tung Chung	Average
2005	95	161	126	130	79	130	130	114	75	116
2006	90	160	131	132	76	126	126	110	75	114
2007	84	162	132	127	76	116	116	104	71	110
2008	89	153	125	129	82	121	121	102	76	111
2009	86	135	109	116	67	108	108	89	68	98
2010	89	143	116	127	72	115	115	97	69	105
2011	86	136	116	120	70	110	110	93	75	102
2012	85	132	116	124	67	109	109	89	69	100

Table4.6 Ambient concentration for RSP for general (non-roadside) stations, measured in $\mu g/m^3$

Year	Central /Western	Eastern	Kwai Chung	Kwun Tong	Sham Shui Po	Shatin	Tai Po	Tsuen Wan	Yuen Long	Tung Chung	Average
2005	54	49	58	56	56	53	51	58	62	57	55
2006	53	47	58	55	55	52	51	57	62	56	55
2007	53	49	60	53	57	52	53	59	64	54	55
2008	51	46	52	47	53	50	50	53	60	52	51
2009	47	43	47	48	47	45	46	49	51	46	47
2010	47	43	45	47	48	45	45	45	49	45	46
2011	50	43	48	49	51	47	46	50	54	47	49
2012	46	38	42	43	42	39	41	42	44	45	42

Table 4.7 Ambient concentration for NOx for roadside stations, measured in $\mu g/m^3$

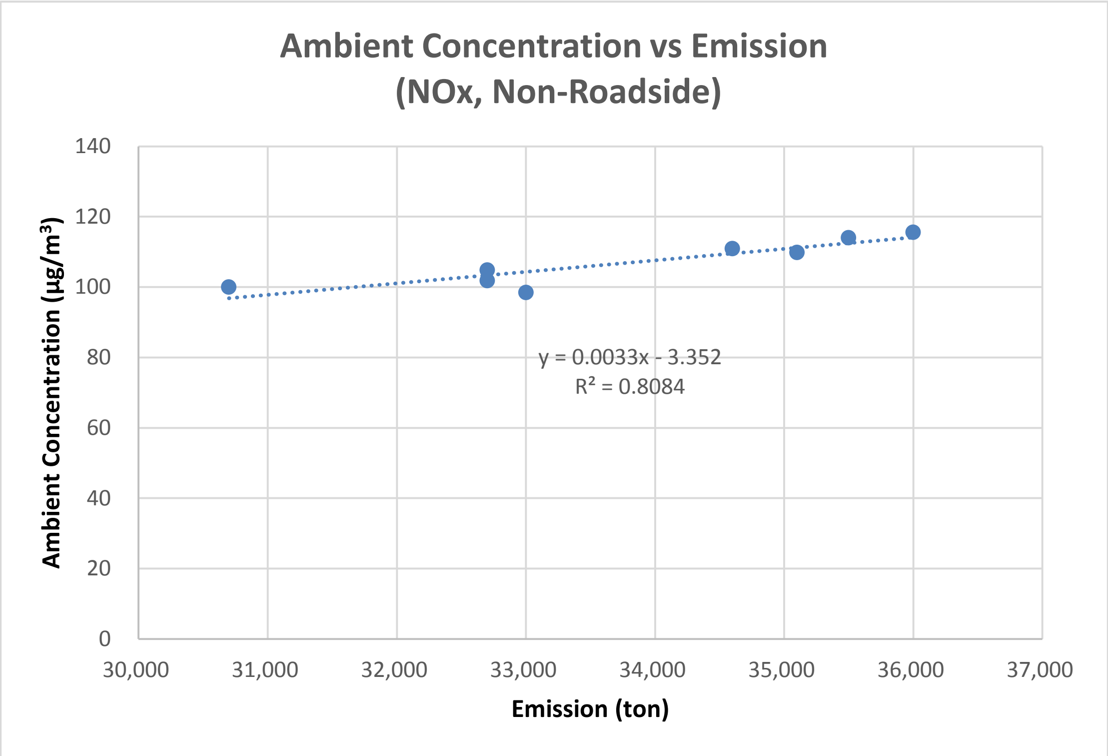
Year	Causeway Bay	Central	Mong Kok	Average
2005	383	366	319	356
2006	384	344	335	354
2007	341	343	324	336
2008	350	350	293	331
2009	317	322	302	314
2010	312	336	305	318
2011	344	326	309	326
2012	313	303	321	312

Table 4.8 Ambient concentration for RSP for roadside stations, measured in $\mu g/m^3$

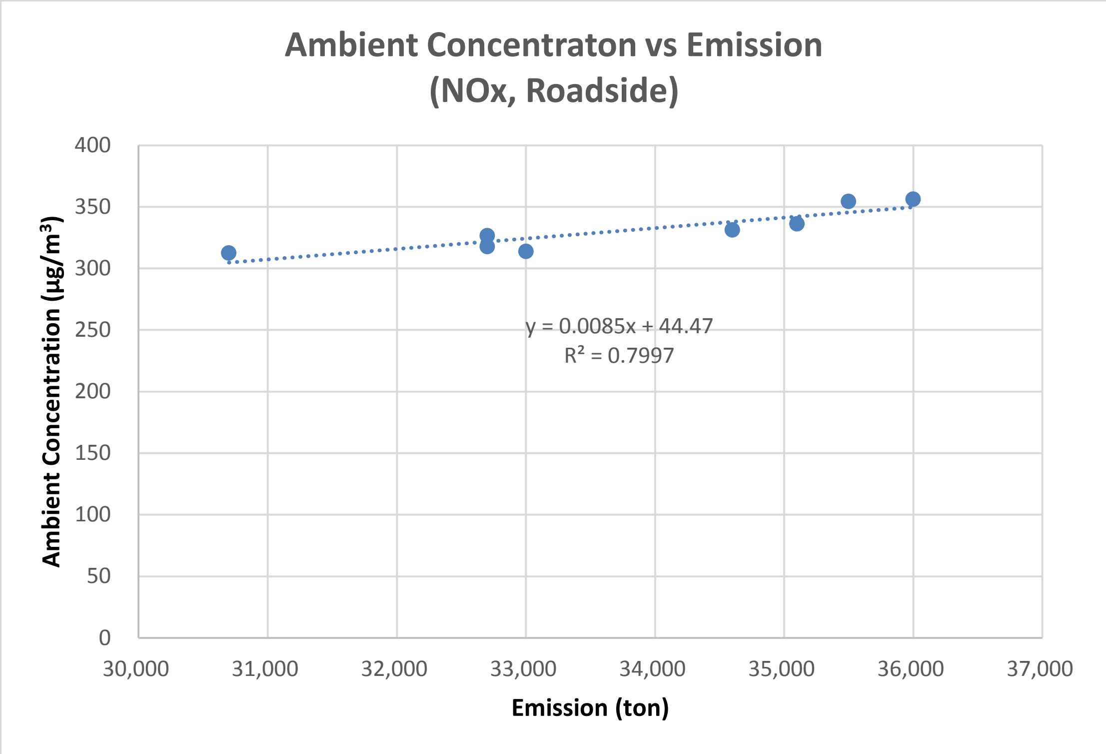
Year	Causeway Bay	Central	Mong Kok	Average
2005	84	72	69	75
2006	83	75	67	75
2007	85	68	66	73
2008	79	63	62	68
2009	71	58	55	61
2010	66	59	55	60
2011	66	62	55	61
2012	61	51	47	53

4.10 By plotting the ambient concentration of pollutants against the emissions by road transport, a fairly linear relationship can be observed in the following graphs:.

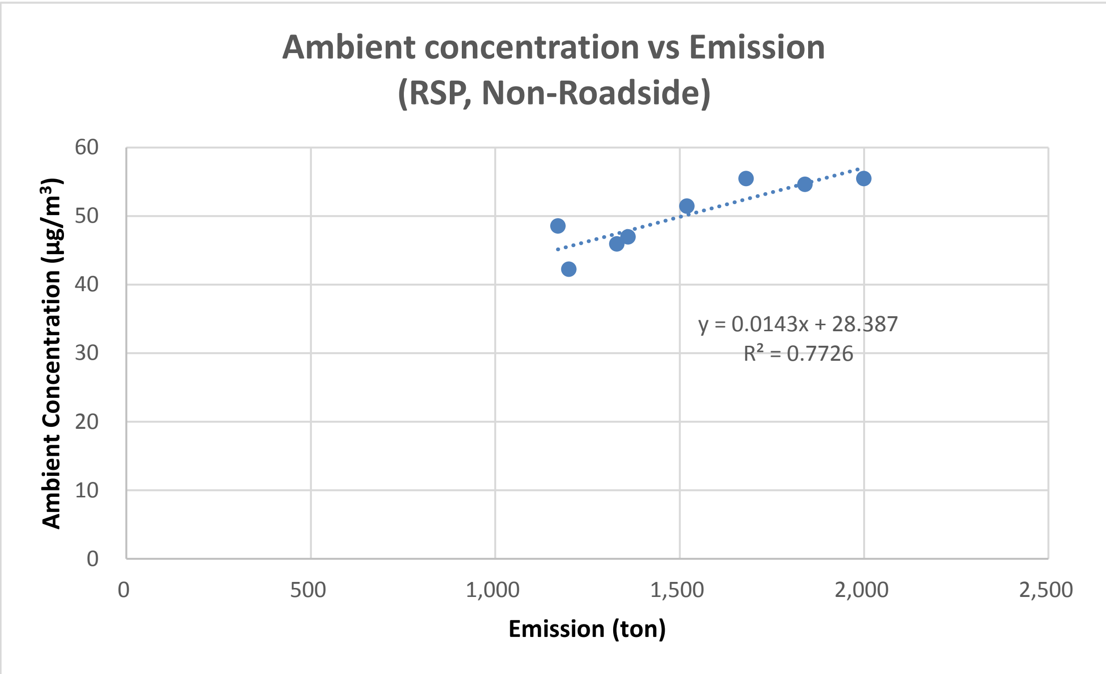
Graph 4.1



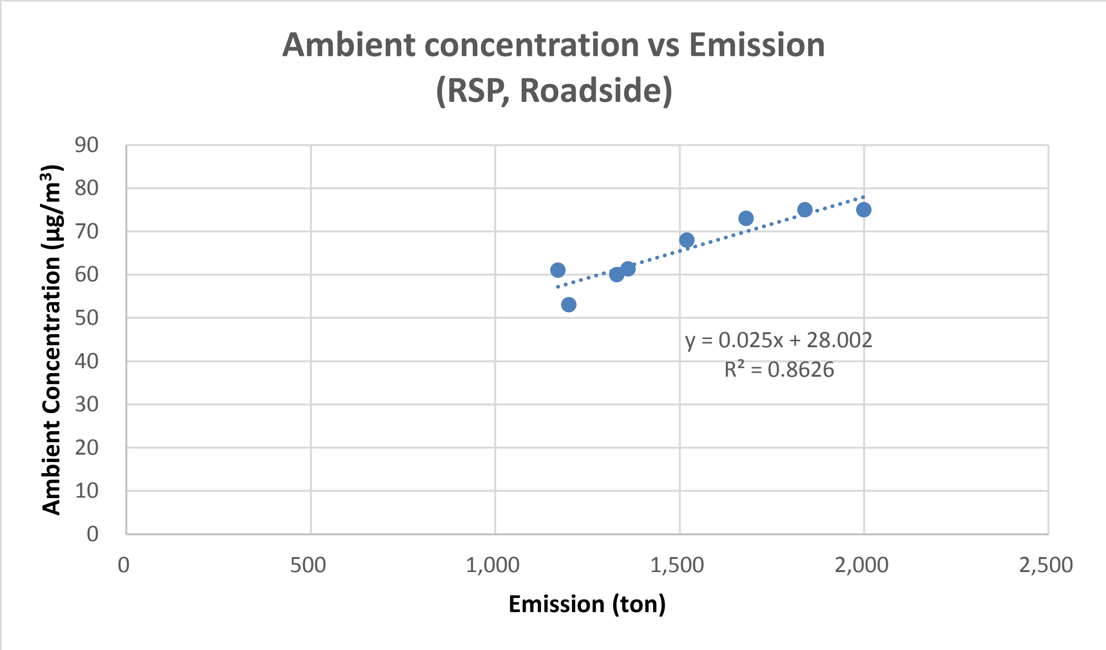
Graph 4.2



Graph 4.3



Graph 4.4



4.11 It is observed that the correlation between ambient annual average concentration of NO_x and RSP and the total emission of pollutants by road transport is strong. Under non-roadside condition, a decrease in 1 ton emission of NO_x can lead to a drop of 0.0033 $\mu g/m^3$ of annual average NOx concentration of the territory. Similarly a decrease in 1 ton emission of RSP can lead to a drop of 0.0143 $\mu g/m^3$ of annual average RSP concentration of the territory. On the other hand, under the roadside condition, a decrease in 1 ton emission of NOx can lead to drop in the annual average concentration of NO_x by 0.0085 $\mu g/m^3$ and 1 ton RSP emission can lead to a drop in the annual average concentration of RSP by 0.025 $\mu g/m^3$.

<u>Conversion of Nitrogen Oxide (NOx) to Nitrogen Dioxide (NO_2)</u>

4.12 According to various epidemiological studies [11], nitrogen dioxide is the primary concern among the nitrogen oxides for cardiovascular and respiratory diseases. As the relationship observed in Graphs 4.1 and 4.2 is between NOx and total emission, it is necessary to convert the observed NO_x to NO_2 for further analysis.

4.13 It is understood that in the presence of Ozone (O_3), nitrogen monoxide will be oxidized to nitrogen dioxide ($NO + O_3 \rightarrow NO_2 + O_2$). In general, the higher the ambient ozone level, the higher will be the NO_2/NO_x ratio as more NOx is converted to NO_2. The concentrations of Nitrogen Dioxide measured by EPD [14] are shown below in **Table 4.9** for non-roadside stations and in **Table 4.10** for roadside stations, the respectively. For NO_2/NO_x ratio, the data are shown in **Tables 4.11 & 4.12** for non-roadside and roadside stations, respectively.

Table 4.9 Ambient concentration for NO_2 for general (non-roadside) stations, measured in $\mu g/m^3$.

Year	Central /Western	Kwai Chung	Kwun Tong	Sham Shui Po	Shatin	Tai Po	Tsuen Wan	Yuen Long	Tung Chung	Average
2005	58	63	58	65	42	49	61	58	46	56
2006	54	58	61	67	43	57	64	58	47	57
2007	53	61	63	69	45	53	64	55	46	57
2008	52	66	59	69	44	52	64	56	49	57
2009	51	64	58	65	40	45	61	52	45	53
2010	54	65	59	69	42	46	63	54	44	55
2011	54	67	63	70	45	45	64	54	51	57
2012	52	64	59	68	43	51	61	49	43	54

Table 4.10 Ambient concentration for NO_2 for roadside stations, measured in $\mu g/m^3$

Year	Causeway Bay	Central	Mong Kok	Average
2005	95	99	93	96
2006	95	96	97	96
2007	90	100	101	97
2008	96	102	96	98
2009	109	112	108	110
2010	116	122	113	117
2011	124	123	120	122
2012	117	117	120	118

Table 4.11 NO_2/NOx ratio for general (non-roadside) stations

Year	Central /Western (%)	Kwai Chung (%)	Kwun Tong (%)	Sham Shui Po (%)	Shatin (%)	Tai Po (%)	Tsuen Wan (%)	Yuen Long (%)	Tung Chung (%)	Average (%)
2005	61	39	46	50	53	38	47	51	61	50
2006	60	36	47	51	57	45	51	53	63	51

2007	63	38	48	54	59	46	55	53	65	53
2008	58	43	47	53	54	43	53	55	64	52
2009	59	47	53	56	60	42	56	58	66	55
2010	61	45	51	54	58	40	55	56	64	54
2011	63	49	54	58	64	41	58	58	68	57
2012	61	48	51	55	64	47	56	55	62	56

Table 4.12 NO_2/NOx ratio for roadside stations

Year	Causeway Bay (%)	Central (%)	Mong Kok (%)	Average (%)
2005	25	27	29	27
2006	25	28	29	27
2007	26	29	31	29
2008	27	29	33	30
2009	34	35	36	35
2010	37	36	37	37
2011	36	38	39	38
2012	37	39	37	38

4.14 It is observed that the nitrogen dioxide to nitrogen oxides ratio shows a rising trend in the past few years. It is due to the increase in concentration of ozone which enhances the nitrogen monoxide to nitrogen dioxide conversion. The average NO_2/NOx of the latest year (2012) has been adopted in this study, i.e. 56% for non-roadside condition and 38% for roadside condition. There's no ozone data for roadside stations until 2011.

Table 4.13 Ambient concentration for Ozone (O_3) for general (non-roadside) stations, measured in $\mu g/m^3$.

Year	Central /Western	Eastern	Kwai Chung	Kwun Tong	Sham Shui Po	Shatin	Tai Po	Tsuen Wan	Yuen Long	Tung Chung	Average
2005	36	31	23	31	25	40	34	25	32	38	32
2006	38	40	19	32	25	40	37	24	32	37	32
2007	39	31	28	31	27	45	38	29	36	40	34
2008	37	38	31	33	27	43	45	31	35	41	36

2009	40	43	33	37	30	46	48	32	41	47	40
2010	37	42	28	33	28	45	38	30	34	44	36
2011	36	46	28	37	31	43	48	31	39	44	38
2012	37	40	30	40	27	47	34	32	39	47	37

Calculation of the benefits from improvement in air quality due to new railway line

4.15 After knowing the reduction in emission of NOx and RSP from road traffic attributable to the operation of a new railway line, the decrease in ambient concentration of NOx and RSP due to reduction in emission can be determined. The decrease in NOx concentration can be further translated into NO_2 concentration which is the primary concern for health. With decrease in ambient concentration of NO_2 and RSP, we can calculate the cost saving on air pollutant related diseases.

4.16 The calculation of costs involves the Excess Risks (ER) factor [15] which is estimated from a statistical model for daily variations of each health outcome for all ages; the Excess Risks for a 10 µg/m^3 change in pollution concentration for various situations is shown in **Table 4.14**.

Table 4.14 Excess Risks for a 10 µg/m^3 change in pollution concentration for mortality, Hospital admissions and general practitioner visits [15]

	ER (%) per 10 µg/m^3	
	NO_2	RSP
Mortality – Respiratory Disease	0.81	0.40
Mortality – Cardiovascular Disease	0.94	0.37
Hospital admissions – Respiratory Disease	0.54	0.50
Hospital admissions –Cardiovascular Disease	0.73	0.37
General practitioner visits– Respiratory Disease	2.98	1.42

4.17 Taking hospital admissions due to respiratory disease as an example, the Excess Risks (ER) per 10 µg/m^3 for NO_2 is 0.54% [15]. If the total number of hospital admissions due to respiratory disease for that year is 1000, an increase in concentration of NO_2 by 10 µg/m^3 will lead to an increase in hospital admissions due to respiratory disease by 1000*0.54%=5.4 more admissions; a decrease in concentration of pollutants will lead to decrease in hospital admissions vice versa.

4.18 The total costs include Direct Costs of Illness due to air pollution and Productivity Loss due to health impacts of air pollution [7][15].

Direct Costs of Illness due to air pollution

4.19 The Direct Cost of Illness (COI) is the cost of health services related to cardiovascular and respiratory disease. This includes (a) admissions to public hospitals, (b) admissions to private hospitals, (c) visits to Accidental and Emergency Departments, (d) visits to specialty, (e) visits to general outpatient clinics and (f) visits to private general practitioners.

4.20 The total Direct Cost of Illness is calculated by:

Total Direct Cost of Illness =
(A) The cost per episode/visit * (B) total number of episode/visit in a year * excess risks (ER) ………………………………………………………………… (3)
Where (A) the cost per episode/visit =
Average Cost for each Bed-Day (ACBD)* Mean Length of Stay (LOS) for an episode ……………………………………………………………………… (4)

4.21 **Table 4.15** below illustrates the calculation of Direct Cost of Illness due to a hypothetical 10μg/m^3 change (reduction) in air pollutants. The figure and money terms in the table are extracted from“West Island Line/South Island Line: Direct External Benefits” published by the University of Hong Kong for the purpose to demonstrate the calculation. The data is for Hong Kong Island in Year 2000.

Table 4.15 Annual Direct Cost of Illness (HK$) due to each 10μg/m^3 change in air pollutant [15]

	(A) Cost per episode (HK$)	(B) Total no. of episodes per year	Direct Cost of Illness per 10μg/m^3 (COI=A*B*ER)	
			NO_2	RSP
(a) Hospital admissions – Public Hospitals				

Respiratory Disease			**(A*B*0.54%)**	**(A*B*0.50%)**
1. Acute General				
F	18,541.44 (ACBD-aR1F x LOS-aR1F=$3,132 x 5.92)	10,292	1,030,474	954,143
M	18,322.20 (ACBD-aR1M x LOS-aR1M=$3,132 x 5.85)	15,283	1,512,098	1,400,091
2. CR Infirmary				
F	51,773.55 (ACBD-aR2F x LOS-aR2F=$2,735 x 18.93)	970	271,190	251,102
M	49,968.45 (ACBD-aR2M x LOS-aR2M=$2,735 x 18.27)	1,225	330,541	306,057
3. Coronary Care Unit				
F	17,276.04 (ACBD-aR3F x LOS-aR2F=$5,188 x 3.33)	121	11,288	10,452
M	16,082.80 (ACBD-aR3M x LOS-aR2M=$5,188 x 3.10)	149	12,940	11,982
Cardiovascular Disease			**(A*B*0.73%)**	**(A*B*0.37%)**
1. Acute General				
F	19,919.52 (ACBD-aC1F x LOS-aC1F=$3,132 x 6.36)	8,413	1,223,355	620,057
M	18,792.00 (ACBD-aC1M x LOS-aC1M=$3,132 x 6.00)	8,963	1,229,559	623,201
2. CR Infirmary				
F	54,745.70 (ACBD-aC2F x LOS-aC2F=$2,735 x 20.02)	1,574	629,142	318,880
M	56,970.05 (ACBD-aC2M x LOS-aC2M=$2,735 x 20.83)	1,319	548,548	278,031
3. Coronary Care Unit				
F	19,403.12 (ACBD-aC3F x LOS-aC2F=$5,188 x 3.74)	131	18,555	9,405
M	18,054.24 (ACBD-aC3M x LOS-aC2M=$5,188 x 3.48)	137	18,056	9,152
	Cost for item (a)		**6,835,747**	**4,792,551**

(b) Hospital admissions – Private Hospitals				
Respiratory Disease			**(A*B*0.54%)**	**(A*B*0.50%)**
F&M	19,403.12 (ACBD-bR x LOS-bR=$3,132 x 5.88)	6,374	633,877	586,923
Cardiovascular Disease			**(A*B*0.73%)**	**(A*B*0.37%)**
F&M	19,403.12 (ACBD-bC x LOS-bC=$3,132 x 6.17)	3,511	495,291	251,038
	Cost for item (b)		**1,129,168**	**837,961**
(c) Accident & Emergency Visit				
Respiratory Disease			**(A*B*0.54%)**	**(A*B*0.50%)**
F&M	571	64,865	200,005	185,190
Cardiovascular Disease			**(A*B*0.73%)**	**(A*B*0.37%)**
F&M	571	48,587	202,525	102,650
	Cost for item (c)		**402,530**	**287,839**
(d) Specialty Outpatient Clinic Visit				
Respiratory Disease			**(A*B*0.54%)**	**(A*B*0.50%)**
F&M	660	60,716	216,392	200,363
Cardiovascular Disease			**(A*B*0.73%)**	**(A*B*0.37%)**
F&M	660	45,480	219,123	111,062
	Cost for item (d)		**435,514**	**311,425**
(e) General Outpatient Clinic Visit				
Respiratory Disease			**(A*B*2.98%)**	**(A*B*1.42%)**

Department of Health	219	151,334	987,636	470,618
Hospital Authority	302	21,764	195,867	93,333
Cardiovascular Disease			**(A*B*2.98%)**	**(A*B*1.42%)**
Department of Health	219	113,357	739,790	352,518
Hospital Authority	302	16,302	146,711	69,909
	Cost for item (e)		**2,070,005**	**986,378**
(f) Private General Practitioner Visit				
Respiratory Disease			**(A*B*2.98%)**	**(A*B*1.42%)**
F&M	174	5,306,284	27,514,144	13,110,767
	Cost for item (f)		**27,514,144**	**13,110,767**
	Annual total Direct Cost		**38,387,108**	**20,326,921**

Note:

1. F:Female, M:Male
2. ACBD-aR1F is the Average Cost per Bed Day for (a) Public Hospitals Admission,(R) due to respiratory disease, (1) stay in acute general, (F) for female patient. The notation is also used for Mean Length of Stay (LOS)

Productivity Loss due to health impacts of air pollution

4.22 Productivity Loss (PL) assesses the indirect cost due to morbidity and mortality. Productivity Loss may be due to absence from work, time of travel and life loss from deaths.

4.23 The calculation of Productivity Loss is similar to that of Direct Cost of Illness, which is formulated as:

Productivity Loss =
(A) The Productivity Loss per event * (B) total number of event in a year * excess risks (ER) …………………………………………………………………… (5)
The full calculation of indirect costs due to Productivity Loss is illustrated in **Table 4.16** below.

Table 4.16 Annual Productivity Loss (HK$) due to each 10μg/m^3 change in air pollutant

	(A) PL per event (HK$)	(B) Total no. of events per year	Productivity Loss per 10μg/m3 (PL=A*B*ER)	
			NO2	RSP
(a) Hospital admissions – Public Hospitals				
Respiratory Disease			**(A*B*0.54%)**	**(A*B*0.50%)**
4. Acute General				
F	1,136.22 #	951^	5,835	5,403
M	2,118.58 #	2,451 ^	28,040	25,963
5. CR Infirmary				
F	1,699.07 #	58 ^	532	493
M	4,020.16 #	143 ^	3,104	2,874
6. Coronary Care Unit				
F	781.15 #	11 ^	46	43
M	1,270.36 #	22 ^	151	140
Cardiovascular Disease			**(A*B*0.73%)**	**(A*B*0.37%)**
4. Acute General				
F	1,328.22 #	1,118 ^	10,840	5,494
M	2,004.16 #	2,651 ^	38,785	19,658
5. CR Infirmary				
F	3,135.12 #	160 ^	3,662	1,856
M	6,304.44 #	330 ^	15,187	7,698
6. Coronary Care Unit				
F	799.56 #	15 ^	88	44
M	1,226.96 #	33 ^	296	150
	PL for item (a)		**106,567**	**69,816**
(b) Hospital admissions – Private				

Hospitals				
Respiratory Disease			**(A*B*0.54%)**	**(A*B*0.50%)**
F&M	1,604.55 #	2,598 ^	23,016	21,311
Cardiovascular Disease			**(A*B*0.73%)**	**(A*B*0.37%)**
F&M	1,666.85 #	1,249 ^	15,198	7,703
	PL for item (b)		**38,213**	**29,014**
(c) Private General Practitioner Visit				
Respiratory Disease			**(A*B*2.98%)**	**(A*B*1.42%)**
1. Sick leave	55.89 @	2,491,501 +	4,149,650	1,977,350
2 Waiting & travelling time	20.55 ~	2,491,501 +	1,525,770	727,045
	PL for item (c)		**5,675,420**	**2,704,395**
(d) Premature death				
Respiratory Disease			**(A*B*0.81%)**	**(A*B*0.40%)**
F	96,000 =	197 >	153,187	75,648
M	144,000 =	388 >	452,53	223,488
Respiratory Disease			**(A*B*0.94%)**	**(A*B*0.37%)**
F	96,000 =	908 >	819,379	322,522
M	144,000 =	2,189 >	2,963,030	1,166,299
	PL for item (c)		**4,388,160**	**1,787,957**
	Annual total Productivity Loss		**10,208,360**	**4,591,181**

Note:

1 F:Female, M:Male

2 The figure and money terms in the table are extracted from “West Island Line/South Island Line: Direct External Benefits” published by the University of Hong Kong. The data is for Hong Kong Island in Year 2000.

3 #: Mean length of stay (days) x median daily income

@: Mean sick leave (days) x median daily income

~: Mean waiting and travelling time (hour) x median hourly income

^: No. of episodes for working group (aged 15-64) x labour force rate x employment rate

+: No. of consultations x labour force rate x employment rate

=: Median monthly income x 12

>: Total number for those died aged from 15-64

4.24 After calculating the Direct Cost due to Illness (COI) and indirect cost due to Productivity Loss (PL), we can determine the health care cost avoidable from introducing a new railway line. We divide the town or region into roadside population and non-road side population, as below:

Health care cost avoidable for roadside population
= (COI +PL) x POP (roadside) x REDUCTION/10μg/m^3 …………….. (6)

Health care cost avoidable for non-roadside population
= (COI +PL) x POP (non-roadside) x REDUCTION/10μg/m^3 x TRAP ……. (7)

Here, POP (roadside) is the roadside population exposed, which is calculated as POP (roadside) = (population in the region of new railway line/population of the reference region used to determine no. of episodes/events in COI/PL) x roadside population ratio. For example, the population used to determine episodes/events in COI/PL in the previous example is the total population of Hong Kong Island, then POP (Roadside) = (population in the region of new railway line / population of HK Island) x road side population ratio

REDUCTION is the reduction in mean annual pollutant concentrations. This value is determined from our previous steps, by converting reduction in emission to reduction in pollutant concentration.

TRAP is traffic-related air pollutants (in % of total air pollution) for the non-road side population. For NO2, this figure is 66.6% and for RSP, the figure is 38.8%.

4.25 Following on the above calculations, annual total health cost avoidable can be calculated and the results are illustrated in **Table 4.17**:

Table 4.17 Annual total health cost avoidable due to introduction of new railway line [15]

	POP(%) {1}	RS/ NRS (%)	REDUCTION (μg/m3)		TRAP (%)		TOTAL (HK$)	
			NO_2	RSP	NO2	RSP	NO2	RSP

		{2}						
COI								
Roadside	41	49	9.6	8.3	/	/	7,403,491	3,409,871
Non-Roadside	41	51	5.8	5.0	66.6	38.8	3,116,608	831,166
						Sub-total	10,520,099	4,241,037
PL								
Roadside	41	49	9.6	8.3	/	/	1,968,825	770,177
Non-Roadside	41	51	5.8	5.0	66.6	38.8	828,806	187,733
						Sub-total	2,797,631	957,910
						Total	13,317,730	5,198,947

Note:

1. Regional population/reference population (e.g. Western District/Hong Kong Island)
2. Proportion of roadside/non-roadside population in those region
3. The figure and money terms in the table is extracted from "West Island Line/South Island Line: Direct External Benefits" published by the University of Hong Kong for the purpose to demonstrate the calculation. The data is for Hong Kong Island in Year 2000.

5. REVIEW OF STRATEGIC HIGHWAY PROJECT REVIEW SYSTEM (SHPRS) AND APPLICATION OF ENVIRONMENTAL; COST-BENEFIT ANALYSIS TO SHPRS

5.1 According to SHPRS, Economic Internal Rate of Return (EIRR) is the key measure on the economic effectiveness of a project. The general formulation is:

$$NPV = \sum_{i=0}^{n} \frac{Bi-Ci}{(1+r)i} = 0 \quad \text{.......... (8)}$$

Where r = EIRR per annum

i = current year (i = 0 in base year)

Bi = sum of economic benefits in year i

Ci = sum of economic costs in year i

n = end of project life in years from base year

The economic costs include

(a) Capital-costs;
(b) Recurrence costs; and
(c) Other costs.

The economic benefits include
(a) Savings in vehicle operating costs;
(b) Savings in travelling time costs;
(c) Changes in accident costs;
(d) Changes in environmental costs; and
(e) Others

5.2 For economic costs and internal economic benefits (such as fare, advertisement income etc.), MTRC will estimate the benefits (including tangible and intangible) for operating a new railway line at the capital-budgeting stage of project implementation.

5.3 While for item (d) - Changes in the environmental costs, the current version of SHPRS suggested that only the changes in the quantity of air pollutant emissions be assessed, without including their monetary implications. The objective of this Study is to suggest a methodology for calculating the economic benefits in money terms. Hence the economic benefits in environmental terms can be included in the general formulation (8) above for determination of EIRR.

5.4 Specifically, it is considered in this Study that the health cost from morbidity and mortality due to air pollution is one of the major environmental costs. When a new railway line is introduced, there will be significant improvement of air quality and hence a reduction in health cost. A major change in environmental costs of a highway project, as suggested in SHPRS is the reduction of health cost.

5.5 For example, it has been estimated that the annual total health costs avoidable due to introduction of new railway line and the corresponding economic costs and benefits are given in the **Table 5.1**:

Year	2020	2021	2022
Annual Total Health Cost avoidable	20M	22M	25M
Other Economic Benefits	200M	250M	230M
Total Economic Cost	200M	60M	70M

5.6 If the initial investment at the beginning of 2020 is HKD250M, then we have:

$$-250M + \frac{(20M+200M)-(200M)}{(1+r)} + \frac{(22M+250M)-(60M)}{(1+r)2} + \frac{(25M+230M)-(70M)}{(1+r)3} = 0$$

And the EIRR, which is r in the general formula, is calculated to be 24.22%.

6. CONCLUSIONS

6.1 A Phase 1 Study has been carried out on the potential transport, economic, social and environmental costs and benefits arising directly or indirectly from the introduction of a new rail line in Hong Kong.

6.2 This study aims to give an overview of the costs and benefits, followed by the formulation of a scheme for evaluating the benefits from improvement of air quality and in particular the costs avoidable from reduction of air pollutants from road transport. This study has drawn on the emission and measured air quality data in Hong Kong by EPD and the research studies by University of Hong Kong.

6.3 The proposed scheme may be used to evaluate the costs to be avoided from morbidity and mortality due to improvement of air quality for a planned rail line by MTRC.

6.4 A summary of the identified benefits in this Study is given below:

Transport and Economic Benefits:

1. Reduction in the number of vehicles purchased [Para 3.1]
2. Reduction in the number of vehicle operators [Para 3.2]
3. Reduction in demand for new roads and carparks [Para 3.3]

Social Benefits:

1. Preventing unpredictable road congestion and accidents [Para 3.4]
2. Helps relieving tiredness and enhancing productivity [Para 3.5]
3. Boosting regional economic activity [Para 3.6]
4. Helps achieving the strategy planning of city [Para 3.7]
5. Enhancing mobility and accessibility [Para 3.9]

Environmental Benefits:

1. Reduction of fuel consumption [Para 3.11]
2. Reduction of traffic noise [Para 3.12]
3. Reduction of light pollution [Para 3.13]
4. Reduction of the cost of air pollution related disease [Section 4]

6.5 The Phase 1 Study provides a framework for evaluating the costs avoidable from reduction of air pollutants. In the subsequent phases, we suggest that the health benefits from operating a new railway line, e.g. Tseung Kwan O line, can be studied using the framework developed in this Phase 1 Study. This will involve gathering data from the Transport Department and MTRC for the shift of passengers from road vehicles to railway and the data can be used to determine the reduction in traffic emissions. Next, we can compare the air pollution data from EPD before and after opening the new line to estimate the improvement in air quality. Hence we can estimate the health cost avoided due to reduction of traffic emissions from this railway line.

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