PolyU Technology & Consultancy
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CONSULTANCY SERVICE

FOR

TRANSPORT DEPARTMENT

FINAL REPORT
on Cost Benefit Analysis for Retrofitting Seat Belts on Franchised Buses

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Signed by: ____________

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1. INTRODUCTION

1.1 Background

On 10 February 2018, a double-decked bus flipped onto its side on Tai Po Road. The crash killed 19 people and injured more than 60. As directed by the Chief Executive of the Hong Kong Special Administrative Region ("Chief Executive"), an Independent Review Committee on Hong Kong's Franchised Bus Service ("IRC") had been set up to, from safety point of view, examine the operation and management of bus franchises, the present regulatory and monitoring system for franchised buses ("FBs"), and to make recommendations to the Chief Executive on safety-related measures with a view to sustaining a safe and reliable FB service in Hong Kong. IRC recommended, in its Report submitted to the Chief Executive in December 2018, that the Transport Department ("TD") should, amongst others, conduct a cost benefit analysis ("CBA") in respect of retrofitting seat belts before requiring FB operators to install seat belts.

1.2 This Report

The TD engaged PolyU Technology and Consultancy Company Limited to conduct a study on review of oversea seat belt requirements and CBA of the retrofitting of seat belts on existing FBs, which commenced on 23 February 2019. The methodologies and findings are set out in this report.

2. SEAT BELT REQUIREMENTS IN OVERSEA JURISDICTIONS

2.1 Methodology

For the existing legislations of fitting and wearing of seat belts on various vehicle types in oversea countries, an extensive literature search via relevant law database (i.e. Lexis-Nexis, Westlaw, and World Legal Information Institute ("WorldLII")), university library service, contact of oversea transport authorities, and personal contacts in oversea research institutions has been conducted. The oversea jurisdictions considered are Australia (Victoria), Canada (British Columbia), European Union, New Zealand, Singapore, United Kingdom ("UK") and the United States ("US").

2.2 Findings

Currently, there is no seat belt requirements on passenger seats on urban buses with standing passengers amongst oversea jurisdictions. In Hong Kong, seat belts were required for exposed seats of FBs. Starting from July 2018, all newly purchased FBs are to be equipped with seat belts on all passenger seats. The summary of the existing legislations with the installation and wearing requirements of seat belts on urban buses in different jurisdictions is shown in **Table 2.1**.

Table 2.1 - Summary of existing legislations for passenger seat belts on urban buses in different jurisdictions

Jurisdiction	Existing legislation		
	Installation requirement	Wearing requirement	Liability
United Kingdom	• All passenger seats *(for urban buses without standing passengers)* • Lap-belt/3-point seat belt	• Mandatory	• Drivers (for passenger aged 3 to 13 inclusive) • Passengers of age 14 or above
Australia (Victoria)	• Only exposed seats *(for urban buses without standing passengers)* • Lap-belt	• Mandatory	• Drivers
Canada (British Columbia)	• No specific requirement was found	• No specific requirement was found	• No specific requirement was found

Jurisdiction	Existing legislation		
	Installation requirement	Wearing requirement	Liability
European Union	• No specific requirement was found	• No specific requirement was found	• No specific requirement was found
New Zealand	• No specific requirement was found	• No specific requirement was found	• No specific requirement was found
Singapore	• No specific requirement was found	• No specific requirement was found	• No specific requirement was found
United States	• No specific requirement was found	• No specific requirement was found	• No specific requirement was found

3. OVERSEA METHODOLOGIES OF COST BENEFIT ANALYSIS

3.1 Overview

CBA has been applied for the evaluation of economic effectiveness of transport management and policy initiatives in the decision-making process in oversea jurisdictions. It provides a framework for organizing information and gauging the advantages and disadvantages of alternatives in terms of economic values. This section reviews the common methodologies of CBA in oversea jurisdictions, particularly for transport policy initiatives.

3.1.1 Cost

Cost considered is usually referring to life-cycle cost, including capital, operating and maintenance costs, and sunk cost for planning and design. Additionally, other costs including finance cost, land cost, funding gap and the residual value would be considered, depending on the nature of the project being assessed (Queensland Government, 2011; New Zealand Transport Agency, 2013; US Department of Transportation, 2018).

3.1.2 Benefits

Benefit refers to the sum of marginal economic effects associated with the enhanced level of service, accessibility and safety (New Zealand Transport Agency, 2013). Unlike the cost, the monetary value of some benefits might not be quantifiable.

(a) Tangible benefit

- It includes travel time savings, operating and maintenance cost savings.
- It may include lower risk of injury and associated medical and insurance costs.
- The monetary values can be derived from the marketplace.

(b) Intangible benefit

- It includes human life saving, improvement of level of service and comfortability, reductions in emission and noise.
- The monetary values might not be quantifiable directly. A standard monetary value could be gauged based on the results of perception survey.

(c) Other benefit

- It includes cultural, historical, aesthetical and ecological effects.
- It may include better company reputation and access to new markets of the public transport operators
- It is unlikely that a standard monetary value could be gauged.

3.2 Estimation of Safety Benefits

For some categories of safety benefits, such as the likelihood of fatalities, injuries and property damages that result from traffic accidents, it might not be possible to derive the monetary value from the marketplace. We could not find any published accident cost in Hong Kong. Nor has there been any similar research done in Hong Kong.

Two major approaches to estimate accident cost in tern of Value of Statistical Life ("VSL") are willingness-to-pay ("WTP") approach and hedonic wage approach. To estimate the VSL, most jurisdictions had adopted WTP approach for onward evaluating the accident cost in term of VSL. The WTP approach for estimation of VSL is based on the amount that individuals are willing to pay for a risk reduction. The WTP approach is used to estimate the accident cost via Stated Preference ("SP") survey or Revealed Preference ("RP") survey. RP relies on the consumer purchase decision basis but it ignores the price risk opportunities, i.e. the price paid for a safety feature might not necessarily represent the value of the marginal safety benefit brought by the feature, e.g. benefits attributed to the usage of safety equipment is difficult to be quantified in its price.

Some jurisdiction, i.e. US, adopted more comprehensive WTP approach, i.e. hedonic wage approach for estimating the VSL. In hedonic wage approach, the wage difference, which an employer is willing to pay for the change in risk level of a job, is used for estimation of VSL. VSL is estimated based on the information from a comprehensive database of labour wage and occupational fatality.

(a) Value of Statistical Life (VSL) (For fatal cases)
VSL is the accident cost of one fatality in a traffic accident. It is an economic value used to quantify one fatality. In general, attributes including medical cost, loss of output, property damage, police cost and legal cost would be taken into account when estimating the VSL.

(b) Value of Preventing Injury (For non-fatal case, such as serious and slight injured)
Compared to fatalities, non-fatal injuries are more prevalent and vary greatly in term of the severity level and likelihood. A standardized approach is to interpolate for deriving the accident cost for non-fatal cases (such as serious and slight injuries cases) as a fraction of VSL based on injury severity as classified in accordance to the US' Maximum Abbreviated Injury Scale ("MAIS").

There are six different injury severity levels under MAIS. The corresponding fraction of each categories with respect to the VSL are follows:- (i) Minor – 0.003; (ii) Moderate – 0.047; (iii) Serious – 0.105; (iv) Severe – 0.266; (v) Critical – 0.593; and (vi) Unsurvivable – 1.000. Having compared the description of severity levels and duration of suffering in MAIS with the injury severity classification in Hong Kong, it is considered appropriate to adopt the fraction of **VSL of 0.003 for slight injury** and **0.105 for serious injury** for the purpose of this study.

3.3 Comparing Benefits to Costs

Net present value ("NPV") and cost-benefit ratio ("CBR") are the two most commonly used indicators to assess the cost effectiveness in CBA (U.S. Department of Transportation, 2018).

(a) Net Present Value
The overall benefit and cost across the treatment's lifetime are discounted to the present values. If the overall benefit exceeds the cost, the NPV (i.e. the net benefit) is positive and an alternative would be considered as economically viable.

(b) Cost-Benefit Ratio
The present value of benefit is divided by the present value of cost. If the CBR is greater than 1, an alternative would be considered as economically viable.

3.4 Concluding Remarks

The CBA approaches and methodologies in oversea jurisdictions, particularly for transport-related projects, were reviewed. We could not find any published accident cost nor similar research in Hong Kong. WTP approach had been widely adopted to estimate the accident cost amongst oversea jurisdictions. To assess the safety benefits of seat belt installation in Hong Kong, it is necessary to estimate the accident cost per injury, anticipated injury reduction associated with installing and wearing of seat belt.

Taking into account of the oversea methodologies, it would be practicable to make reference to the oversea accident cost with consideration of the corresponding GDP per capita.

4. SAFETY EFFECTIVENESS OF SEAT BELT

4.1 Overview

Seat belt was first introduced to motor vehicles by manufacturers in the United States, like Ford, Nash, Volkswagen, Volvo, since early 1950s, and legislation specifying the wearing requirement of seat belts of driver and front seat passenger on motor vehicles was first imposed in 1970s. A seat belt keeps the occupant in his/her seat and prevents him/her from hitting other occupants or the hard interior parts of a vehicle in a collision. Seat belts are designed to absorb energy and spread the impact force over the occupant's entire body by stretching during sudden vehicle deceleration (Hinch et al., 2002).

Regarding the protection by the use of personal safety equipment in traffic accidents, seat belts protect car occupants from colliding with the interior of the car and retain them in their seats in the event of an accident. Seat belts could be regarded as a fundamental component of occupant protection system in motor vehicles.

In Hong Kong, seat belt legislation was first introduced to drivers and front seat passengers of private cars in October 1983. It was further extended to drivers and passengers of taxis and light buses, and the drivers and front seat passengers of goods vehicles in the subsequent years. Indeed, after the introduction of the seat belt legislation, the casualties of drivers and passengers in traffic accidents decreased for all classes of vehicles. A local study by Yau (2004) also indicated that seat belts usage is one of the significant factors affecting injury severity of vehicle accident for goods vehicles, in which unbelted passengers would have 3 times higher risk of fatal and seriously injured than belted passengers.

Nowadays, according to various national laws, seat belts must be installed in the light vehicle fleets in most countries. Among these countries, it is also a legal requirement that the belt must be worn when the light vehicle fleet is moving. It is generally agreed that mandatory seat belt legislation is highly effective in promoting seat belt wearing and is a cost-effective safety tool of minimizing injury and preventing death from road traffic accidents (Stevenson et al., 2008).

4.2 Findings

Majority of oversea research studies were based on the light vehicles. Currently, we could not find study with rigorous evaluation of the effect of seat belts on the injury risk explicitly for heavy vehicles like buses. A state-of-the-knowledge review was conducted to evaluate the effectiveness of seat belts in the protection of occupants, through the literature search of past relevant oversea studies since 1960, laboratory tests, empirical studies, and diagnostic analysis of relevant crash records, in particular for the jurisdictions with the requirements of fitment and usage of seat belt being in force.

In 2009, a meta-analysis of 29 studies was conducted by Institute of Transport Economics in Norway (Elvik et al., 2009). This study first provided the best estimate of safety effectiveness of seat belt by integrating the results of different studies conducted before 2000, with respect to road environment, crash scenario and occupant characteristics using rigorous statistical approach. Results indicated that seat belts were found 25% effective at preventing fatal injuries and serious injuries, and 20% effective at preventing minor injuries of rear seat passengers respectively.

In 2016, the same research group (i.e. Institute of Transport Economics in Norway) revisited the issue by conducting an updated meta-analysis based on 24 oversea studies after 2000 (Hoye, 2016) (see **Appendix 1**). Results indicated, for rear seat passengers, the mean reduction of fatality was 44% and that of serious and slight injury was 65% respectively, whereas the confounding factors including accident time, crash severity, driver behaviour, speed and speed limit were controlled for. The analysis included the studies from Finland, France, Germany, Italy, Netherlands, Spain, Sweden, United Kingdom and United States during the period from 2002 to 2010.

Although the aforementioned study in 2016 was conducted on light vehicles while this CBA is for heavy vehicles like FBs, it is still considered appropriate for adopting the above findings for the purpose of this CBA. It is because (i) safety effectiveness of seat belt for heavy vehicles including buses and goods vehicles should be higher than that for light vehicles as the front-rear and rollover crashes (where seat belt could provide better protection) were more profound for heavy vehicles and more passengers will be involved, thus the extent of injury reduction by seatbelts should only be higher in the case of buses; and (ii) safety effectiveness of seat belt should be improved because of the advances in vehicle construction technology with interaction with the seat belts over the years. Yet, no evidence could be established for statistically significant differences in safety effectiveness between light and heavy vehicles. In the subsequent cost-benefit analysis, the following estimates shown in **Table 4.1** would be adopted for injury reduction of rear seat passengers by seat belt. The estimates were established based on rigorous statistical analysis, whereas the possible bias were eliminated.

Table 4.1 - Estimates of injury reduction of rear-seat passengers by seat belt*

Injury severity	Injury reduction
Fatal	44%
Serious Injury	65%
Slight Injury	65%

**Reference: Hoye, A. (2016) "How would increasing seat belt use affect the number of killed or seriously injured light vehicle occupants?" - Accident Analysis and Prevention 88 (pages 175-186)*

To conclude, seat belt is an effective protection measure for vehicle occupant, despite that the safety effectiveness may vary with vehicle and seat belt type, crash circumstances, and occupant attributes. For the children, seat belt can enhance the overall protection of the restraint system, especially in the case of catastrophic events such as side or lateral impact collision by a large vehicle or vehicle rolling over.

5. ACCIDENT ANALYSIS FOR FRANCHISED BUSES IN HONG KONG

To assess the safety performance of FBs in Hong Kong, a diagnostic analysis of the corresponding accident and injury records has been conducted. All crashes resulting in personal injury are recorded by the Hong Kong Police Force and the traffic accident database are maintained by TD in the Transport Information System ("TIS"), in which comprehensive information on accident environment, vehicle particulars and casualty characteristics are available.

As per the TD's traffic accident databases, the overall number of casualties and casualty rate involving FBs from 2009 to 2018 (Transport Department, 2019) are shown at **Appendix 2**. Overall, 15,060 passengers on FB were injured from 2009 to 2018. There were significant reductions in the casualty rates between 2014 and 2016. Nevertheless, both the number of casualties and casualty rates increased remarkably from 2016 to 2018. This reflects the increase in per unit accident risk of FB, given that the passenger patronage, licensed FB and kilometre operated all increased during the same period.

To estimate the safety benefit of retrofitting seat belt on FB, it is necessary to deduce the relevant casualties that would be benefited from the seatbelts from 2009 to 2018. **Table 5.1** presents the number of casualties involving seated passengers on double decked FBs, by injury severity and year, from 2009 to 2018. As shown in **Table 5.1**, from 2009 to 2018, on average, there are 1.1 fatalities, 50.4 serious injuries, and 596.6 slight injuries respectively, per year.

Table 5.1 - Casualties involving seated passengers on double decked FBs in 2009-2018

Year	Severity			Total
	Killed	Serious	Slight	
2009	2	44	613	659
2010	1	47	688	736
2011	0	49	660	709
2012	0	55	645	700
2013	0	67	739	806
2014	0	41	571	612
2015	0	28	440	468
2016	1	32	372	405
2017	2	52	606	660
2018	5	89	632	726
Total	11	504	5,966	6,481
Average	*1.1*	*50.4*	*596.6*	

6. SAFETY BENEFITS

6.1 Overview

For accident cost saving, we could not find any published accident cost and VSL in Hong Kong. Nor has there been any similar research done in Hong Kong so far. To estimate the accident cost, the main components are medical costs (e.g. cost of hospitalization, rehabilitation, and other medical treatment), production loss (e.g. loss of production or productive capacity), human costs (e.g. pain, and loss of quality of life), property damage, and administrative cost (e.g. police, fire service, insurance and legal costs). Medical cost, production loss and human costs are more often included in accident cost estimation (Wijnen *et al.*, 2018).

6.2 Findings

In view of the tight timeframe of the study, it is not practical to conduct a perception survey for working out the VSL in Hong Kong, which would anticipate to take some years for completion with reference to oversea experience. After reviewing the oversea methodologies on the CBA, reference was made to the VSL and the corresponding gross domestic product ("GDP") per capita in local currency unit ("LCU") from 10 jurisdictions (i.e. Australia, Canada, China (Nanjing), Japan, South Korea, the Netherlands, New Zealand, Singapore, UK and US) for estimating the accident cost for the purpose of this CBA study.

Table 6.1 summarizes the latest updated VSL and GDP per capita (in LCU) of the captioned 10 oversea jurisdictions. Additionally, ratios of VSL to GDP per capita are estimated. The average ratio of the 10 concerned jurisdictions is 79.0.

Table 6.1 - VSL and GDP per capita of jurisdictions under investigation

Jurisdiction	Year	GDP per capita (LCU)*	VSL (million LCU)	VSL to GDP Ratio
US	2016	57,588 (USD)	9.60 (USD)	166.7
Japan	2007	4,153,782 (YEN)	360.00 (YEN)	86.7
Canada	2008	49,718 (CAD)	4.05 (CAD)	81.5
South Korea	2006	19,944,027 (WEN)	1480.00 (WEN)	74.2
New Zealand	2017	60,435 (NZD)	4.21 (NZD)	69.7
The Netherlands	2017	42,793 (EUR)	2.90 (EUR)	67.8
China (Nanjing)	2014	107,545 (RMB)	7.18 (RMB)	66.8
Australia	2014	67,893 (AUD)	4.20 (AUD)	61.9
UK	2017	30,862 (GBP)	1.90 (GBP)	61.6
Singapore	2015	75,533 (SGD)	4.05 (SGD)	53.6
			Average	**79.0**

**Source: World Bank Open Data (The World Bank, 2019)*

In Hong Kong, GDP per capita was HK$ 381,870 in 2018 (Census and Statistics Department of HKSAR, 2019). Adopting the average VSL to GDP ratio (i.e. 79.0) based on the VSL in the above jurisdictions shown in **Table 6.1** above, an VSL of **HK$ 30.2 million (2018 price)** was derived for the purpose of this study. The average VSL to GDP ratio was used to establish the benchmark of relative VSL with that of economic performance, which is one of the contributory factors that affect the safety perception and willingness-to-pay. The safety benefit and the cost of retrofitting seatbelts on FB would be referred to the price level in 2018 for comparison under this CBA study.

With reference to the appropriate fraction of VSL, the annual safety benefit is summarised in **Table 6.2**. Also, as per the information from the bus manufacturers, only the seats on the upper deck can be technically feasible for retrofitting (i.e. 70% of the seats). Therefore, only 70% of all seated passengers could be protected. It should be noted that other intangible safety benefits including enhanced reputation of FB operators because of the improvement in the level of service are not included in this CBA study, since it is difficult to establish the monetary value from the marketplace.

Table 6.2 - Annual safety benefit of retrofitting seat belts

Injury Severity	VSL (HK$ in 2018 price)	Annual average number of casualties involving seated passengers on double decked FBs (from 2009 to 2018)	Fraction of VSL	Injury reduction by seat belts	% of all passenger seats which can be retrofitted	Annual safety benefit of retrofitting seat belts (HK$ in 2018 price)
Killed	30.2M	1.1	1.000	44%	70%	10.2M
Serious	30.2M	50.4	0.105	65%	70%	72.7M
Slight	30.2M	596.6	0.003	65%	70%	24.6M
					Overall Total	**107.5M**

Note:
For each category of injury severity, Annual safety benefit = VSL x Annual average number of casualties x Fraction of VSL x Injury reduction by seat belts x Percentage of all passenger seats which can be retrofitted.

7. COST OF RETROFITTING SEAT BELT

7.1 Existing Vehicle fleet

To stock take the number of existing vehicles among FBs, the information on vehicle make, vehicle model, year of manufacture/registration, residual servicing period and seating capacity, etc. are collected from the Vehicles and Drivers Licensing Integrated Data ("VALID") system of TD. As at August 2019, there were 6,315 registered FBs. The distribution of FB vehicle fleets by operator and estimated year of disposal is illustrated at **Appendix 3** .

7.2 Selected Models

For the FBs, majority are double-decked buses with seating capacity of 80 or more. Major vehicle manufacturers of FBs are Volvo, ADL and Man. Typically, the completely equipped vehicles (with seats, seat belts and other accessories installed), are imported to Hong Kong.

As per information from bus manufacturer, for the fitting of seat belt on new vehicles, it is technically feasible for fitting of seat belt, with marginal additional cost as compared with the procurement cost of a new vehicle. Also, for the existing vehicles, retrofitting seat belt on the upper deck is technically feasible, given that the floor structure and bus body have sufficient strength to comply with relevant requirements. However, it is not appropriate to establish the technical feasibility for retrofitting seat belt on the lower deck, as it largely depends on the conditions of the original structure members of the body structure of lower deck and vehicle chassis. There could be technical constraints to modify the body structure of lower deck and vehicle chassis to cope with the requirement of seat assembly and seat anchorage for the fitment of seat belts.

Table 7.1 presents the information on the vehicle make, vehicle model, seating capacity, and type approval code of 7 selected FB models (consider that the total seating & standing capacity and layout plan may vary) for investigation. As shown in **Table 7.1**, the selected models constitute to 1,731 vehicles. For each of these vehicles, number of seats to be retrofitted with seat belt in the upper deck is 54, since five exposed seats are already fitted with seat belt. Regarding the vehicle models, they are the products of ADL (Trident E500), Volvo (B9TL) and Man (ND363F). The selected models will yield a reasonable result on the cost estimate of retrofitting seat belts for about 30% of double decked FBs in Hong Kong.

Table 7.1 - Selected FB models (with type approval code as at 31 December 2018)

Brand	Model	Total Capacity (Upper/Lower/Standees)	Type approval code (No. of vehicle)
ADL	Trident E500	136 (59/31/46)	AD040ADD600 (365)
		137 (59/31/47)	AD040ADD700 (511)
		136 (59/31/46)	AD045ADD600 (244)
		136 (59/31/46)	AD045ADD60B (100)
Volvo	B9TL	138 (59/31/48)	VV020WRD800 (133)
		137 (59/31/47)	VV024WRD700 (349)
Man	ND363F	130 (59/27/44)	MN0C1GLD000 (29)

Information with respect to different vehicle model, seating capacity, seating layout, and seat and seat belt types has been gathered from the major bus manufacturers. In computing the implementation cost for retrofitting seat belts, factors including procurement cost of seat with integral seat belt, workmanship, reinforcement of body structure, and testing and inspection have been taken into consideration. In addition, the time required for preparation, installation, construction of body structure, testing and inspection, and their impacts on the operation of existing vehicle fleets have been considered.

7.3 Cost of Retrofitting

Table 7.2 presents the information on cost estimates for three popular double decked FB models, i.e. ADL (Trident E500), Volvo (B9TL) and Man (ND363F). For instances, the procurement cost of seat with integral seat belt, workmanship, reinforcement of body structure, and testing and inspection are considered for the estimation. The total cost of retrofitting seat belt, for 54 seats on the upper deck, is estimated to be HK$200,000 (2018 price) per vehicle.

Table 7.2 – Cost Breakdown for retrofitting seat belt on FB

	Vehicle Model		
	ADL (Trident E500)	**Volvo (B9TL)**	**Man (ND363F)**
No. of seat to be retrofitted	54	54	54
Cost			
Seat with integral seat belt	HK$ 130,000	HK$ 129,924	HK$ 120,000
Structural reinforcement		HK$ 22,507	HK$ 74,242
Workmanship	HK$ 50,000	HK$ 41,810	
Testing and inspection	HK$ 5,758	HK$ 5,758	HK$ 5,758
Total	HK$ 185,758	HK$ 200,000	HK$ 200,000

The impacts of retrofitting on the actual operation of existing vehicle fleets should be taken into account when estimating the cost. As per the information from the vehicle manufacturers, retrofitting of seat belt on one FB would take about one week, including installation, inspection and testing. For the cost implications on suspending service due to retrofitting, in view of the scales of FB vehicle fleets and operators have already maintained adequate fleet size to cater for maintenance and routine vehicle inspection, it is considered that the disruption to FB operation could be kept as minimal and the cost is considered insignificant and would not be included when estimating the cost in this study.

8. COST BENEFIT ANALYSIS

8.1 Cost

As suggested by the vehicle manufacturer, it is technically feasible to retrofit seat belts on the majority of passenger seats at the upper deck of certain existing FB models manufactured by ADL (E500 after 2013), Volvo (B9TL) and Man (after 2014). Overall, it is technically feasible to retrofit about 3,825 existing double decked FBs. On average, 700 FBs can be retrofitted every year since the end of 2019.

Priorities could be given to the FBs with longer residual servicing period to maximize the benefit. As stated in preceding section, costs of retrofitting seat belt add up to about HK$200,000 (2018 price) for each bus. **Table 8.1** presents the total cost of retrofitting FBs with respect to the registration year.

Table 8.1 - Cost of retrofitting seat belt on FBs

Registration year	Disposal year	No of Vehicle*	Retrofitting time (year)	Servicing period (year)	Total cost (HK$ in 2018 price)
2010	2028	42	0.06	3.57	$8.4M
2011	2029	183	0.26	4.73	$36.6M
2012	2030	61	0.09	5.90	$12.2M
2013	2031	303	0.43	7.16	$60.6M
2014	2032	446	0.64	8.70	$89.2M
2015	2033	827	1.18	10.61	$165.4M
2016	2034	830	1.19	12.79	$166.0M
2017	2035	582	0.83	14.80	$116.4M
2018	2036	489	0.70	16.56	$97.8M
2019	2037	62	0.09	17.96	$12.4M

* *According to the information provided by the FB operators in August 2019, 62 FBs purchased before 1 July 2018 and registered in 2019 are technically feasible to be retrofitted with seat belts.*

8.2 Safety Benefit

Table 8.2 presents the total safety benefit of retrofitting seat belt and the servicing period of the concerned FB fleets that are technically feasible for retrofitting seat belts.

Table 8.2 - Safety benefit of retrofitting seat belt on FBs

Registration year	Disposal year	No. of Vehicle	Servicing period (year)	Total benefit (HK$ in 2018 price)
2010	2028	42	3.57	$2.7M
2011	2029	183	4.73	$15.6M
2012	2030	61	5.90	$6.5M
2013	2031	303	7.16	$39.2M
2014	2032	446	8.70	$70.1M
2015	2033	827	10.61	$158.6M
2016	2034	830	12.79	$192.0M
2017	2035	582	14.80	$155.8M
2018	2036	489	16.56	$146.5M
2019	2037	62	17.96	$20.1M

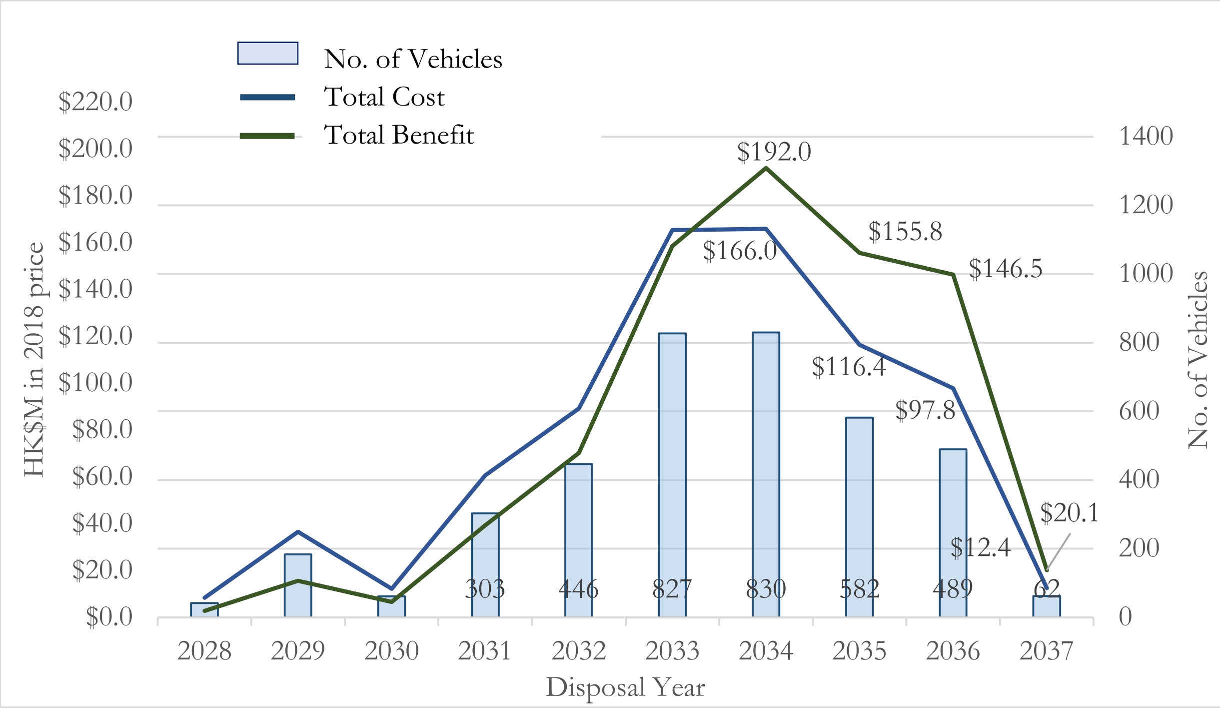
8.3 Cost-Benefit Ratio

Table 8.3 and **Figure 8.1** present the results of CBA of retrofitting FBs with respect to the registration year. According to the CBA findings, 1,963 FBs which were registered in 2016 or later (i.e. to be disposed at 2034 or later) are considered economically viable (with positive net benefit and cost-benefit ratio greater than one) and hence retrofitting seat belts at the upper deck is justified. Therefore, the total net benefit is HK$121.7 million (2018 price) and overall cost-benefit ratio is 1.40 respectively.

Table 8.3 – Cost benefit analysis of retrofitting seat belt on FBs

Registration year	Disposal year	No. of Vehicle	Total cost (HK$ in 2018 price)	Total benefit (HK$ in 2018 price)	Net benefit (HK$ in 2018 price)	Cost-benefit ratio
2010	2028	42	$8.4M	$2.7M	-$5.7M	0.32
2011	2029	183	$36.6M	$15.6M	-$21.0M	0.43
2012	2030	61	$12.2M	$6.5M	-$5.7M	0.53
2013	2031	303	$60.6M	$39.2M	-$21.4M	0.65
2014	2032	446	$89.2M	$70.1M	-$19.1M	0.79
2015	2033	827	$165.4M	$158.6M	-$6.8M	0.96
2016	2034	830	$166.0M	$192.0M	$26.0M	1.16
2017	2035	582	$116.4M	$155.8M	$39.4M	1.34
2018	2036	489	$97.8M	$146.5M	$48.7M	1.50
2019	2037	62	$12.4M	$20.1M	$7.7M	1.62

Figure 8.1 - Cost and benefit of retrofitting seat belt on FBs



9. CONSIDERATIONS OF PRIORITY ON BUS DEPLOYMENT

To maximize the safety benefit brought to passengers by FBs retrofitted with seat belt, consideration should be given to setting priorities in deploying the FBs retrofitted with seat belts to the relevant bus routes. When deploying these buses to the bus routes, consideration of the characteristics of bus routes should be taken into account so as to maximize the safety benefit of the seat belt brought to passengers. Priorities should be given to bus routes in two tiers.

The highest priority should be given to bus routes operating on roads with higher speed limit (i.e. expressways, followed by roads of speed limit of 70km/hr or above) and among the routes operating on roads of the same speed limit (e.g. expressways), priority should be given to those operating with longer journey distance per single trip.

9.1 Speed limit

Bus routes operating on roads with higher speed limit should be given primary consideration (e.g. expressways, followed by roads with speed limit of 70 km/hr or above). As the injury severity is correlated to speed, passengers travelling on buses operated via roads with higher speed might suffer from a higher risk for more serious injury. In addition, bus stops are seldom found along expressway (except Tuen Mun Bus-bus-interchange (BBI) or other BBIs at tunnel toll plaza, which just outside/near the boundary of expressway. Therefore, buses travelling on expressway usually operate at a higher speed for a longer duration. As a result, it is considered that those routes operating on expressways should be given higher priority with buses fitting seat belt. It would then be followed by the routes operating on the roads with speed limit of 70 km/hr or above.

9.2 Journey distance

Additionally, bus routes of long-haul services should be given secondary consideration. In particular, those with longer total journal distance should be given higher priority of implementation. It is observed that passengers more tend to nap in a long distance trip and they might suffer from a higher risk for more serious injury as passengers taking a nap will have a slower response/longer response time to any changes in the surrounding environment. Moreover, long-haul passengers tend to be more willing to wear seat belts as they might feel more relieve to take rest during the journey while short-haul passengers might be less willing to wear seat belts as they just travel on bus for a short while and will get off quickly. Therefore, among the routes operating on the roads of the same speed limit, priority should be given to those operating with longer journey distance.

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APPENDIX 1: SUPPLEMENTARY INFORMATION

In 2016, an oversea research study provided the mean estimates of safety effectiveness of seat belt, based on the comprehensive review of 24 studies published during the period from 2000 to 2012, using meta-analysis approach. Overall, the mean injury reduction of rear-seat passengers by seat belts was 44% for fatality and 65% for serious & slight injuries respectively (Hoye, 2016). **Table A** summarizes the scope and findings of the 24 studies reviewed by the said study.

Table A - Studies on the safety effectiveness on injury reduction by seat belt

No.	Literature	Country	Study period	Vehicle type	Key findings
1	Angel and Hickman, 2009	United States (US)	1995-2004	Private cars, vans, sport utility vehicles, pickup trucks	(i) Seatbelts reduce the odds of fatal injury by 85% or more; (ii) Three-point belts were found to be more effective at preventing outcomes ranging from non-incapacitating injuries to fatalities; (iii) Child restraints were determined to significantly reduce the probability of suffering any type of injuries (odds ratio ranging from 0.38 for possible injury to 0.09 for fatality).
2	Bedard et al., 2002	US	1975-1998	All single vehicle crashes	(i) Wearing seatbelts halved the risk of fatal injuries; (ii) Odds of fatality would have been 23% lower among the sample of belted drivers, compared with non-belted drivers.
3	Braver et al., 2008	US	1998-2005	Private cars, pickup trucks, sport utility vehicles, minivans	The risk ratio of "unbelted" status increased to more than 3.
4	Crandall et al., 2001	US	1992–1997	Private cars	(i) Lap-shoulder belt use reduced mortality by 72%; (ii) Combined air bag and seat belt use reduced mortality by more than 80%.
5	Cummings et al., 2002	US	1990–2000	Private cars, pickup trucks, vans, sport utility vehicles	(i) Among restrained passengers, the adjusted relative risk of death for those with a passenger air bag was 0.79; (ii) Among unrestrained passengers, the adjusted relative risk was 1.03.
6	Cummings et al., 2003	US	1975–1983	All motor vehicles	The relative risk of death among belted compared with unbelted occupants was 0.39.
7	Cummings, 2002	US	1988–2000	Private cars	The adjusted risk ratio for belted persons was 0.36.
8	Cummins et al., 2011	US	1988–2004	Private cars, light trucks	(i) The seatbelt plus airbag group had a 67% reduction in mortality; (ii) The seatbelt only group had a 51% mortality reduction; (iii) The airbag only group had a 32% mortality reduction. (as compared with the no device group.)

No.	Literature	Country	Study period	Vehicle type	Key findings
9	Dissanayake and Ratnayake, 2007	US	1993–2002	Private cars, vans, pickup trucks	(i) Seat belts were found to be 53% effective in reducing fatal injuries to front seat occupants in private cars; (ii) In other passenger vehicles, effectiveness of seat belts in reducing fatal injuries is 57%; (iii) Seat belts are 52% and 42% effective in reducing incapacitating and non-incapacitating injuries respectively in private cars.
10	Donaldson et al., 2006	US	1996–2001	Private cars, pickup trucks, vans, sport utility vehicles	Not wearing a seat belt resulted in an eight-fold increase in risk of death.
11	Eluru and Bhat, 2007	US	2003	Private cars, pickup trucks, sport utility vehicles, minivan	Reduced injury severity if the driver uses seat belt.
12	Gabauer and Gabler, 2010	US	1997–2007	Private cars, light trucks, vans	(i) Seat belt restrained occupants with an airbag available had a dramatically decreased risk of receiving a serious injury (odds ratio of 0.03); (ii) A similar decrease was observed among those restrained by seat belts, but without an airbag available (odds ratio of 0.03).
13	Jehle et al., 2012	US	2000–2005	Private cars, pickup trucks, sport utility vehicles, vans	Restraint use significantly reduces number of death (odds ratio of 0.225).
14	Lardelli-Claret et al., 2006	Spain	1993–2000	Private cars	44% reduction in the risk of death for restrained rear seat passengers.
15	Martin et al., 2003	France	1996–2000	Private cars	More than 80% reduction in the risk of death for seat belt wearing.
16	Mayrose and Priya, 2008	US	2000–2003	Private cars	(i) The rear (2nd row) seating positions have 29.1% increase in the odds of survival over the front (first row) seating positions; (ii) The rear middle seat has a 25% increase in the odds of survival over the other rear seat positions; (iii) Occupants of the rear middle seat have a 13% increased chance of survival when involved in a crash with a fatality than occupants in other rear seats.
17	McGwin et al., 2003	US	1995–2000	Private cars, light trucks, vans, sport utility vehicles	Compared with completely unrestrained occupants, those using a seat belt alone or in combination with an airbag had a reduced overall risk of injury (relative risk, 0.42 and 0.71, respectively).

No.	Literature	Country	Study period	Vehicle type	Key findings
18	Meyer and Finney, 2005	US	1997–2002	Private cars	The odds of dying are reduced by 82% for seatbelt users.
19	Rivara et al., 2000	US	1993–1996	Private cars, light trucks, vans, sport utility vehicles	86% lower risk observed for the use of automatic shoulder belts with lap belts.
20	Sivak et al., 2010	US	1998–2008	All motor vehicles	The odds of dying are reduced by 81.6% for belted drivers.
21	Smith and Cummings, 2006	US	1990–2001	Private cars, light trucks, vans, sport utility vehicles	(i) 47%-63% lower risk of death for children aged 0–12 years; (ii) 50%-64% lower risk of death for passengers aged 13–29 years; (iii)49%-64% lower risk of death for passengers aged 30–59 years; (iv)29%-49% lower risk of death for passengers aged 60 years or older.
22	Toy and Hammitt, 2003	US	1993–1999	Private cars, sport utility vehicles, vans, pickup trucks	(i) Seat-belt use reduces the injury risk by 75%; (ii) Automatic and manual seat belts reduce a driver's serious injury risk by 49% and 67%, respectively.
23	Yannis et al., 2010	France, Netherlands, Italy, Finland, Sweden, United Kingdom (UK), Germany	2003–2004	Private cars	With regard to seat belt use, it was found that road users who did not use a seat belt have more than double risk of being the fatalities in fatal accidents.
24	Zhu et al., 2007	US	2000-2004	Private cars, light trucks, vans, sport utility vehicles	Traffic crash mortality can be reduced for rear occupants by approximately 55–75% if they use safety belts.

Hoye, A. (2016) How would increasing seat belt use affect the number of killed or seriously injured light vehicle occupants? Accident Analysis and Prevention 88, 175-186.

APPENDIX 2: CAUSALITIES FIGURES INVOLVING FBs in 2009-2018

Number of casualties and causality rates involving FBs in 2009-2018

Year	Passenger patronage ('000)[2]	Licensed FB	km operated ('000)	No. of casualties [1]	Casualty rate		
					per million passenger	per licensed FB	per million vehicle km operated
2009	1,391,314	5,786	483,433	1,407	1.011	0.243	2.910
2010	1,378,404	5,729	472,210	1,553	1.127	0.271	3.289
2011	1,382,620	5,798	466,226	1,479	1.070	0.255	3.172
2012	1,402,953	5,743	469,906	1,627	1.160	0.283	3.462
2013	1,426,426	5,791	462,205	1,742	1.221	0.301	3.769
2014	1,428,611	5,810	443,488	1,408	0.986	0.242	3.175
2015	1,429,137	5,865	446,232	1,375	0.962	0.234	3.081
2016	1,448,401	5,916	445,788	1,297	0.895	0.219	2.909
2017	1,447,783	5,982	447,083	1,463	1.011	0.245	3.272
2018	1,479,819	6,151	447,605	1,709	1.155	0.278	3.818

Notes:

[1] Casualty data involving FB were extracted from TD's traffic accident database (2009-2018).

[2] Data extracted from the Monthly Transport and Traffic Digest of TD (Transport Department, 2019)

APPENDIX 3: DISTRIBUTION OF REGISTERED FBs

Distribution of registered FBs by operator and estimated year of disposal (as at end 2018)

Estimated year of disposal	KMB	NWFB	Citybus (F1)	Citybus (F2)	NLB	LWB	Total
2019 or before	269	71	1	0	0	0	341
2020	307	19	8	0	0	0	334
2021	190	0	0	0	0	0	190
2022	176	0	0	0	0	0	176
2023	47	0	0	0	5	3	55
2024	108	0	0	0	9	5	122
2025	53	0	5	0	8	8	74
2026	20	18	5	0	10	2	55
2027	38	20	18	0	8	11	95
2028	99	20	73	0	14	21	227
2029	231	24	44	2	18	15	334
2030	120	13	115	3	10	18	279
2031	250	31	123	38	14	10	466
2032	262	27	90	28	0	40	447
2033	586	121	93	30	9	26	865
2034	483	93	126	52	5	82	841
2035	412	182	47	52	0	6	699
2036	470	69	26	28	45	15	653
2037	1	44	0	0	0	17	62
Total	4,122	752	774	233	155	279	6,315