PRICE ELASTICITY OF DEMAND AND TRANSIT FARE STRATEGY: A CASE STUDY OF BANGKOK MASS TRANSIT SYSTEM

Ackchai Sirikijpanichkul†
Department of Civil Engineering,
Faculty of Engineering, Kasetsart University,
Bangkok, 10900, THAILAND
+662-797-0999, Email: fengacs@ku.ac.th

Sarintorn Winyoopadit
Office of the Public Sector Development Commission Thailand (OPDC)
Bangkok, 10300, THAILAND
+ 662-356-9999, Email: sarintornw@gmail.com

Abstract
Traffic congestion is a chronic problem of Bangkok. Similar to other metropolises, the city perpetually seeks for alternatives to road travel. Mass rapid transit seems to be the only way out that is expected to mitigate traffic congestion in the city. However, without common ticketing system, travelers need to pay an initial entrance fee every time they enter each transit system. This excess cost tapers the demand and affects the efficient use of the system. This research investigates the influence of fare price on transit use which is measured by price elasticity of demand and proposes the optimum fare price if the common ticketing is used. The analysis is based on the findings from the stated preference survey techniques. Finally, the conclusion on fare level that encourage more patronage, maintain service quality and operator revenue is addressed.

Keywords: Price Elasticity of Demand, Bangkok Mass Transit, Optimal Fare Policy

1. INTRODUCTION

Having realized that road transport will no longer move people and freight efficiently and sustainably in the future, Thailand has come up with a major investment plan to transform itself into a more transit-oriented country. The national roadmap called “Thailand 2020” will involve a massive investment in transportation infrastructure development that is expected to foster Thailand as a strategic hub of ASEAN. According to the plan, approximately 80 percent of the unprecedented 2.2 trillion Baht loan will be spent on upgrading the existing, and establishing a new rail infrastructure network including track doubling, extension of new railway line, completing Bangkok metro line network, and establishing a new High-speed rail network.

Traveling by rail is superior to road by the fact that the transit unit is operated on an exclusive right of way therefore the travel time is predictable and reliable. However, such characteristics limit the access to the system and make rail travel less attractive in the sense that rail passengers need to make several transfers before getting into a station instead of enjoying a door-to-door service as motorists do. Apart from such inconvenience, each transfer affects passenger travel time and cost. Although some measures are proposed to facilitate

† Corresponding author

smooth transfers at intermodal or transfer stations such as installation of Intermodal Transfer Facilities (ITF) or the upgrade of station vicinity to meet Transit Oriented Design (TOD) concept, some passengers still feel uncomfortable to use rail transit as they need to pay an initial entrance fee every time they transfer to another transit system especially those who travel in group or make a very short-distance trip.

Common ticketing system comes in place to solve this problem as it allows travelers to transfer as often as they can via one common ticket and one common rebated entrance fee. Then the fare will be calculated based on distance travelled or number of zones crossed regardless of how many transfers are made during the course of the journey. The implementation of common ticketing system in Bangkok is under process and expected to be alive in the next five years. Before that happens, it is necessary to understand how the new fare structure will change the way people travel by investigating how transit demand change in accordance with the change in transit fare which can be explained by the economic measures called price elasticity of demand. In this study, the measures are determined based on the result of field survey data using stated preference techniques. Finally, the conclusions on new fare levels that promote transit patronage, maintain service quality and sustain operator revenue are addressed.

2. OVERVIEW OF BANGKOK MASS TRANSIT NETWORK

The existing mass transit network in Bangkok is composed of four distinguishing systems operated independently by different operators as shown in **Figure 1.**

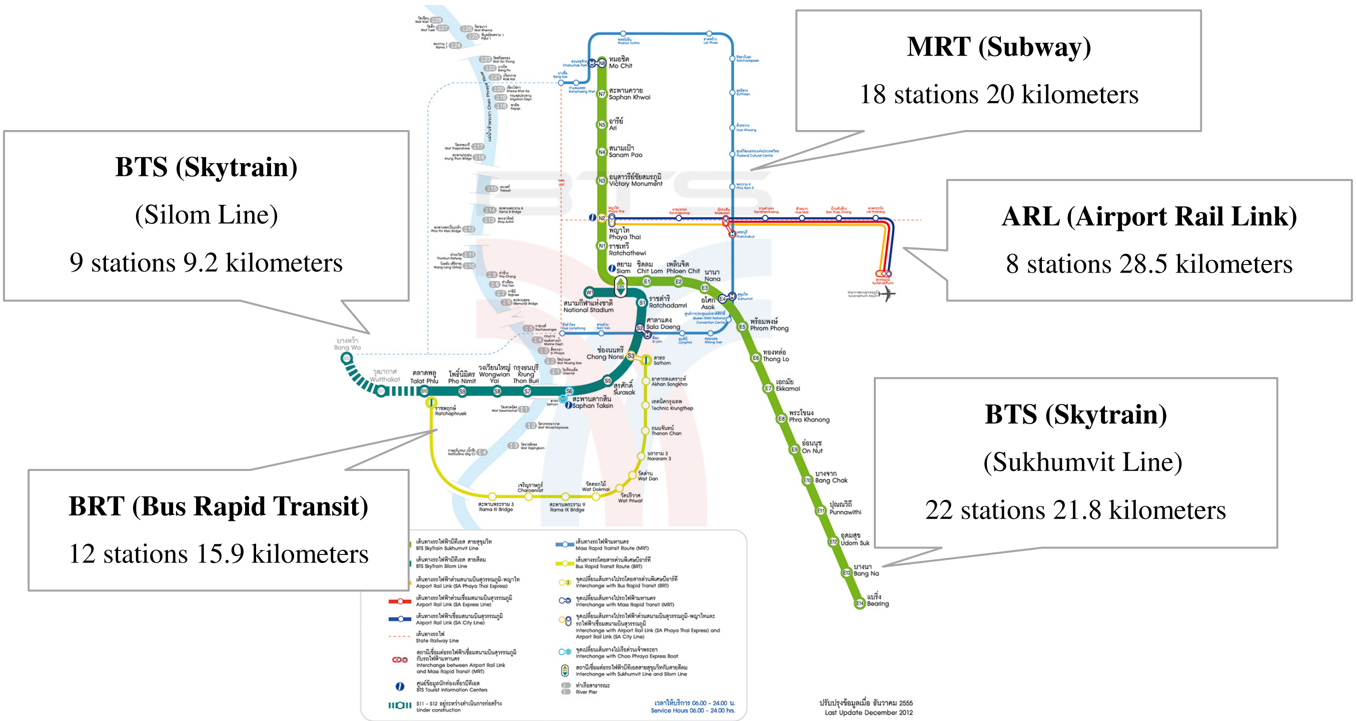


Figure 1: The existing mass transit network in Bangkok
(Source: Bangkok Mass Transit System Public Company Limited).

The current fare strategies of all mass transit lines are typically distance-based where every passenger needs to pay an initial entrance fee every time they enter a transit system or transfer to another transit system then the fare level varies afterwards subject to the distance traveled. The fare structure of a single journey for each transit system in Bangkok is shown in **Figure 2.**

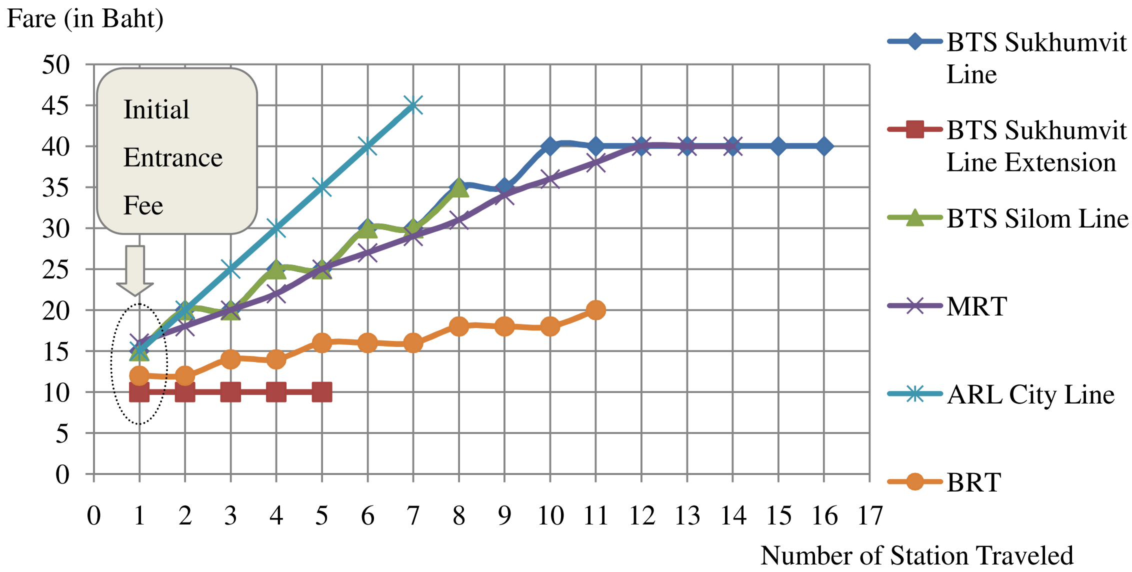


Figure 2: The current fare structure of a single journey for each transit system in Bangkok (Source: Compiled by the authors).

In the year 2020, Thai government aims at completing the whole mass transit network in Bangkok which includes 10 lines illustrated in **Figure 3.**

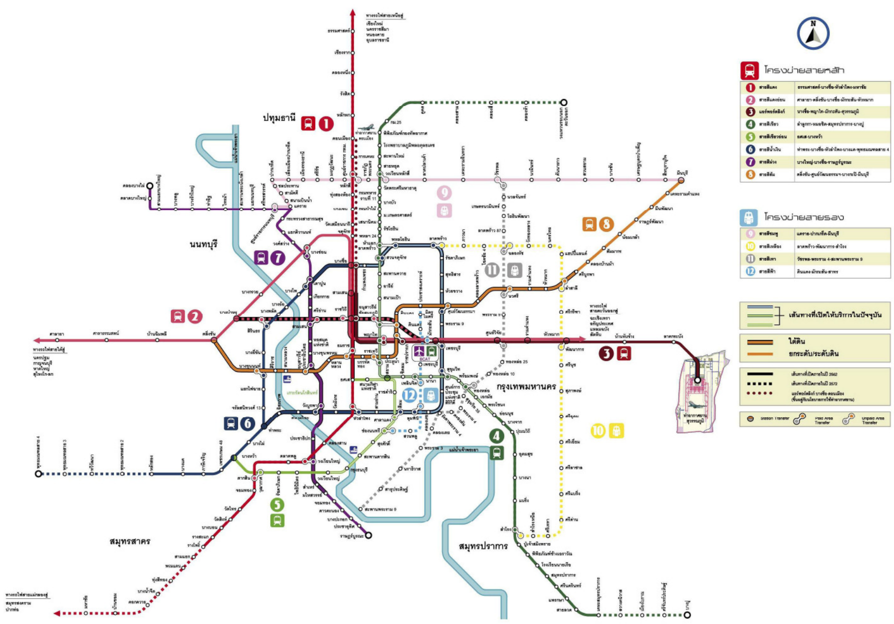


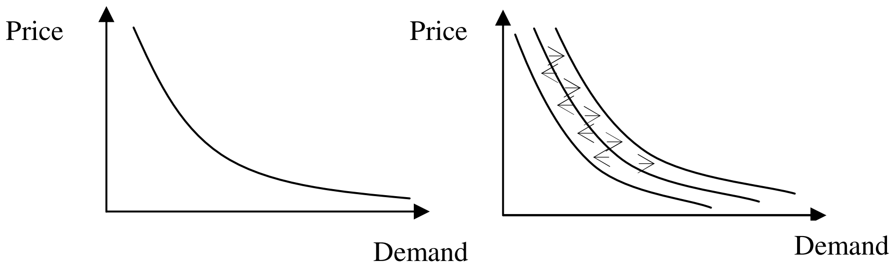
Figure 3: The complete mass transit network in Bangkok 2020 perspective (Source: Office of Transport and Traffic Policy and Planning, Ministry of Transport).

The key concern raised as a research problem is, without an integrated fare structure, passengers are likely to pay an extremely high cumulative fare especially those who live in the remote areas and inevitably forced to make several transfers before reaching their destination. In such cases, the government effort to shift travel demand from road to rail may not be satisfactorily achieved. The next session explains how transit fare affects passenger demand and also the influencing factors that affect passenger perception on transit fare.

3. INFLUENCE OF TRANSIT FARE ON PASSENGER DEMAND

3.1 Price and Demand

Basically, when the price of any goods or service is increased, people tend to buy lower amount of such goods or service, and vice versa, when the price of goods or service is scaled down, people tend to buy more amount of such goods or service, This common behavior is explained by “the economics law of demand” (Marshall 1920). Public transit demand behaviors also obey the same law as depicted in **Figure 4A**. Nevertheless, different groups of people may have different *willingness to pay* for the same transport service subject to their *preference* on the service as illustrated by the *shift in demand* shown in **Figure 4B**. Litman (2004) reviewed the influencing factors that affect passengers’ preference on public transit service and concluded that demographics, commercial activities, transport options, land use, demand management, and prices were the primary factors. Among all, prices are the direct, perceived costs of using a service. Transport price normally reflects both direct (out-of-pocket) and indirect travel costs including travel time, discomfort and risk.



A **B**

Figure 4A: Market demand curve. **Figure 4B:** Shift in market demand.

3.2 Price Elasticity of Demand

The degree of changes in demand subject to change in service characteristics is measured by an *elasticity of demand*. If all the influencing factors are controlled except price, the degree of change in demand $(\frac{\Delta D}{D})$ subject to change in price $(\frac{\Delta P}{P})$ is called a *price elasticity of demand* (E_d) as defined by **Equation 1** (Parkin et al. 2002).

$$E_d = \frac{\left(\frac{\Delta D}{D} \times 100\right)}{\left(\frac{\Delta P}{P} \times 100\right)} = \frac{\Delta D}{D} \cdot \frac{P}{\Delta P} \qquad (1)$$

Each range of the price elasticity of demand (E_d) can be interpreted as shown in **Table 1.**

Table 1: Interpretation of price elasticity of demand (E_d)

Range of Elasticity of Demand (E_d)	Descriptive Terms (Parkin et al. 2002)	Definition
$E_d = 0$	Perfectly inelastic demand	No matter how price is changed, there will be no effect on demand.
$-1 < E_d < 0$	Inelastic or relatively inelastic demand	The change in demand is behind the change in price.
$E_d = -1$	Unit elastic, unit elasticity, unitary elasticity, or unitarily elastic demand	The change in demand affects the change in price at the same scale.
$-\infty < E_d < -1$	Elastic or relatively elastic demand	The change in demand advances the change in price.
$E_d = -\infty$	Perfectly elastic demand	Changing of price at marginal scale, affects demand significantly.

Litman (2012) found that changes in transit fare can affect passengers on their trip frequency, route, mode, destination, scheduling, vehicle type, parking location, type of services selected and location decisions. Such changes also affect operators' revenue as shown in **Equation 2** where Revenue (R) is a multiplication of Price (P) and (D).

$$R = P \times D \qquad (2)$$

The relationship between the change in transit fare and the change in operators' revenue for each demand type can be expressed in **Table 2**.

Table 2: The relationship between the change in transit fare (ΔP) and the change in operators' revenue (ΔR).

Change in Transit Fare (ΔP)	Type of Elasticity of Demand (E_d) / Change in Operators' Revenue (ΔR).		
	Elastic ($-\infty < E_d < -1$)	Unit Elastic ($E_d = -1$)	Inelastic ($-1 < E_d < 0$)
P increased ($+\Delta P$)	Revenue decreased ($-\Delta R$)	Revenue unchanged	Revenue increased ($+\Delta R$)
P decreased ($-\Delta P$)	Revenue increased ($+\Delta R$)	Revenue unchanged	Revenue decreased ($-\Delta R$)

3.3 Influencing Factors on Price Elasticity of Demand

According to the literature review by Litman (2004), McCollom and Pratt (2004), TRL (2004), Paulley et al. (2006), Taylor et al. (2009), Wang (2011), Wardman and Shires (2003 and 2011), the price elasticity of transit demand is influenced by the following factors:

- **User characteristics:** High earners tend to be less price-sensitive but more quality-sensitive in comparison to low earners.
- **Trip characteristics:** Non-commuting trips (for recreational purposes) tend to be more price-sensitive than commuting trips (for business and educational purposes).
- **Mode and route**: Captive riders tend to be less price-sensitive than choice riders.
- **Geography:** People living in the large congested city tend to be less price-sensitive than those living in the smaller city.
- **Type and direction of price change**: Elasticity tends to be higher for high fare levels. Fare increase tends to cause greater impact on passenger reduction than the same level of fare reduction to increase ridership.
- **Time Period:** Elasticity increases over time as passengers take price changes into their decisions on where to live or work.

3.4 Transit Fare Policy

3.4.1 Objectives

Transit fare policy is specified to fulfill some key objectives including maximization of service patronage, profits, and equity to all target groups including elderly, students, handicaps and workforce.

3.4.2 Constraints

Nevertheless, some constraints need to be taken into account including the price elasticity of demand, which limits alternatives to fare structure, level of services and fare level of competing modes, equity to all target groups, necessity and affordability of the service, ease and convenience for payment and fare collection, and negotiation amongst conflicting objectives.

3.4.3 Influencing Factors

Transit fare policy also relies on some influencing factors include government policies, financial management, designed level of service, operating costs, quantity and quality of competing modes, passenger lifestyle.

3.4.4 Fare Structure

Objectives, constraints and influencing factors are taken into considerations for designing a fare structure which needs to be chosen among the following alternatives: *Flat*, *Zonal*, and *Graduate* of which the definitions, advantages, disadvantages, and examples are summarized in **Table 3**.

Table 3: The definitions, advantages and disadvantages of each fare structure

Fare Structure	Definitions	Advantages	Disadvantages
Flat	A single fare paid regardless of distance travelled.	- Ease and convenience for payment and fare collection.	- Discourage short distance passengers. - Subsidy may be needed to compensate loss of income from long distance passengers
Zonal	The service area is divided into a number of zones. Fares are calculated based on the number of zones boundaries crossed during the trip. A flat fare applied for travel within in a designated zone.	- Suitable for large network.	- Discourage passengers who need to cross several boundaries. - More complicate fare collection system.
Graduate	A passenger initially pays an entry charge every time they enter a transit system, then an additional incremental fare is calculated based on a "pay as you go" basis.	- Rational and equitable for all passenger groups.	- More costly for short-distance and intermodal travelers.

To overcome the shortcoming of the graduate fare structure that charges additional entry fee for every transfer a passenger makes, a *common* or *rebated* fare structure is introduced. Under the *common* or *rebated* fare, the passenger only needs to pay a single *rebated* entry charge regardless of how many transfers he or she makes and pay additional incremental fare based on a "pay as you go" basis considering all the intermediate transit systems between trip origin and destination as a single integrated system. The system requires a *common ticketing* system which supplies an electronic log of every passenger movement to a *central clearing house* that decides how to rebate the boarding charge to each passenger and divide the fare between system operators rationally.

4. RESEARCH METHODOLOGY

The research methodology as shown in **Figure 5** comprises of three major steps, including field survey, price elasticity of demand and transit fare strategy, of which the details are described in the following sub sessions.

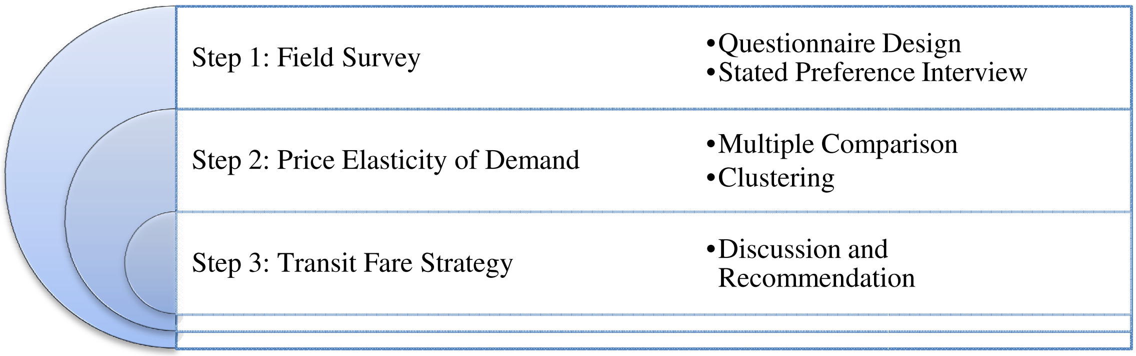


Figure 5: Research methodology.

4.1 Field Survey

A field survey is conducted to acquire a primary dataset on how existing transit passengers and potential users respond to the change in fare level which provides the key input into the analysis of price elasticity of demand. The data are collected via an interview with a questionnaire.

4.1.1 Questionnaire Design

Each questionnaire is designed to reveal the detailed information of the following influencing factors:

- Respondent's characteristics including gender, age, occupation, and monthly income;
- Trip characteristics including trip origin and destination, trip purpose, travel distance, travel time, travel cost, group size, and vehicle occupancy;
- Modes of travel including captive and choice rider, private vehicle only or non-motorized mode only;
- Type of ticket used by transit passengers including Single Journey Ticket (SJT), Stored Value Ticket (SVT), or travel pass;
- Access modes to the transit system including bus, public van, taxi, motorcycle taxi, boat, other transit system;
- Attitudes of users and non-users;
- Sensitivity to changes in transit fare.

4.1.2 Stated Preference Interview

To understand the level of sensitivity to changes in transit fare, it is necessary to simulate a situation where the transit users need to decide "what is the maximum level of fare increase (from the range of hypothetical levels provided) they can tolerate to remain using the transit system ?"; on the other hand, the non-transit users need to decide "what is minimum level of fare decrease (from the range of hypothetical levels provided) they start to shift their current travel modes into transit system ?." This kind of experiment involved *stated preference survey* technique where an individual interviewee is asked to rank or rate the hypothetical options pre-determined by the interviewer.

According to Yamane (1967), to collect the interview data representing population size of more than 100,000 with the expected 95 percent level of confident, at least 400 interview samples are required. For this research, 600 samples of specific target groups mainly include those who have activities inside the coverage area of intermodal transfer facilities are randomly selected and interviewed.

4.2 Price Elasticity of Demand

All the responses from the field survey are filtered, labeled, sorted, and grouped according to the influencing factors as listed in sub-section 4.1.1. For each level of factor, the price elasticity of demand is calculated (see **Equation 1**).

4.2.1 Multiple Comparison

The price elasticity of demand of each factor level is compared under one-way layout experiment to investigate if the changes in factor levels affect the price elasticity of demand so that a rational clustering of the price elastic of demand can be accommodated. The theorem of Welch's t test which is an adaptation of Student's t-test (Wu and Hamada 2000) as shown in **Equation 3** is applicable for this case, where the sample sizes and variance between factor levels are different.

$$\left|t_{ij}\right| = \left|\frac{\overline{E_d}_{\,j.} - \overline{E_d}_{\,i.}}{\sqrt{s_j^2/n_j + s_i^2/n_i}}\right| \tag{3}$$

where

$\overline{E_d}_{\,i.}, \overline{E_d}_{\,j.}$ is the sample mean of price elasticity of demand with factor levels i and j, respectively

s_i^2, s_j^2 is the sample variance of price elasticity of demand with factor levels i and j, respectively

$n_{i.}, n_{j.}$ is the number of samples with factor levels i and j, respectively

4.2.2 Clustering

In this research, the Tukey method is adopted to compare different pairs (and sets) of factor levels simultaneously, when $\overline{E_d}_{\,i.} \neq \overline{E_d}_{\,j.}$ under the studentized range distribution with number of factor levels k and degree of freedom N-k (Total sample size N – number of factor levels k) at 100(1-α) % confidence interval $q_{k,N-k,\alpha}$ (Wu and Hamada 2000) as shown in

Equation 4.

$$\left|t_{ij}\right| = \left|\frac{\bar{y}_{j.} - \bar{y}_{i.}}{\hat{\sigma}\sqrt{1/n_j + 1/n_i}}\right| > \frac{1}{\sqrt{2}} q_{k,N-k,\alpha} \quad (4)$$

Once the pairs or sets of factor levels with indifferent sample means of price elasticity of demand are proven, they will be clustered into groups that have the same level of sensitivity to change in transit fare.

4.3 Transit Fare Strategy

4.3.1 Discussion and Recommendations

Once the price elasticity of demand for each factor level is identified, the optimal fare and fare structure for each transit network can be discussed and recommended.

5. RESEARCH OUTCOMES

5.1 Attitude toward Mass Transit Use

The conclusion on attitudes toward mass transit use from the interview survey is shown in **Figure 6**. The supportive reasons for mass transit use are avoiding traffic jam (46 %), time saving (27 %), and cost saving (22 %); while the contradicting reasons for avoiding mass transit use are poor station access (29 %), expensive fare (28 %), and inconvenience especially in intermodal transfers (20 %)

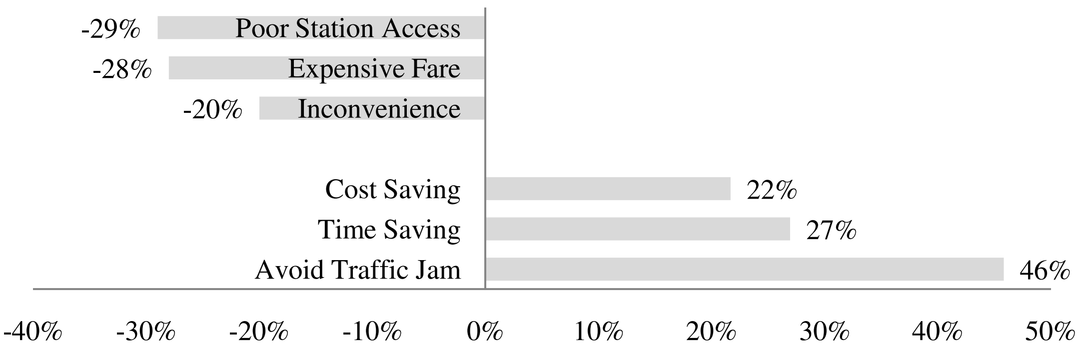


Figure 6: Attitude toward mass transit use.

5.2 Price Elasticity of Demand by Influencing Factor

The price elasticity of demand of each level group of influencing factors including age, distance traveled, income, trip purpose, and ticket type is analyzed and clustered by Tukey method (in shade) as illustrated in **Figures 7 – 11**.

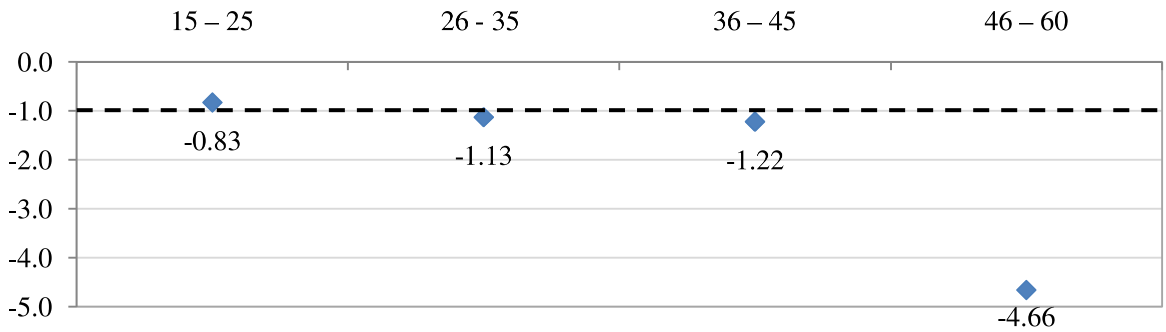


Figure 7: Price elasticity of demand by age group (years)

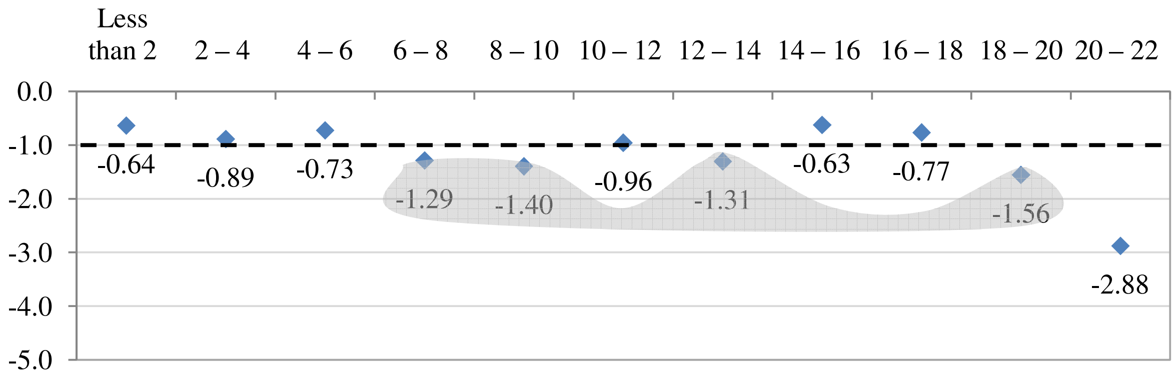


Figure 8: Price elasticity of demand by distance traveled (kilometers)

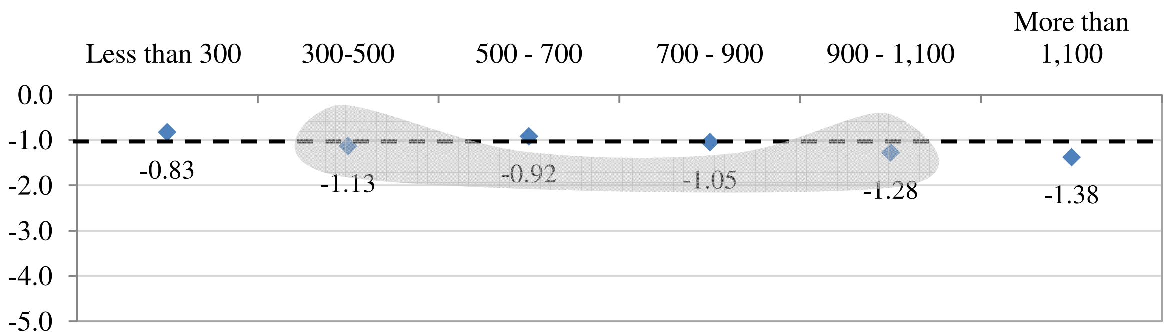


Figure 9: Price elasticity of demand by income (US dollars per month)

The key findings from the analysis are summarized as follows:

- The price elasticity of demand is varied by travelers' age. According to the analysis, the teenagers tend to have inelastic demand ($|E_d| < 1.0$) while the older tend to have higher price elasticity of demand as shown in **Figure 7**, implying that the younger has more necessity to travel with a fewer range of travel choices than the older.
- Most travelers are inelastic to price regardless of how far they travel except for some intermediate ranges where travelers may experience intermodal transfers and are exposed to higher travel costs while for long distance trips, travelers tend to have various choices of travel as shown in **Figure 8**.
- In line with ages, the low income tend to have less price elasticity of demand than the

higher income who have more range of travel choices as shown in **Figure 9**.

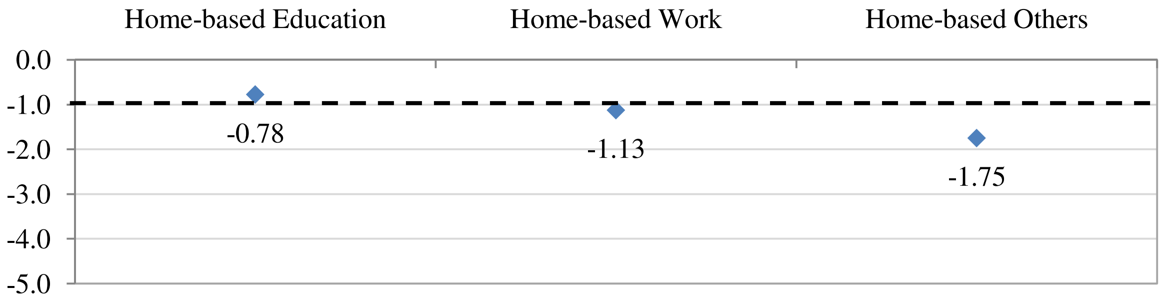


Figure 10: Price elasticity of demand by trip purpose

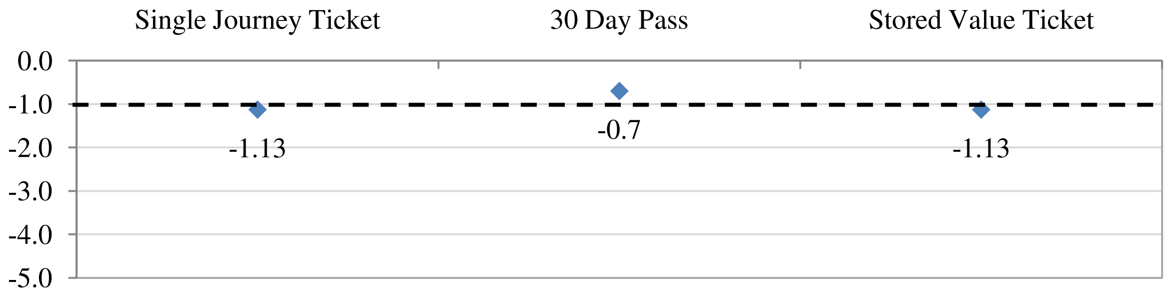


Figure 11: Price elasticity of demand by ticket type

- Education and work purposes tend to have less price elasticity of demand than shopping or recreational trips, respectively, as shown in **Figure 10**.
- Travelers using monthly pass (30 day pass) with some offered discount tend to have less price elasticity of demand than those who use single journey ticket and stored value ticket which are subject to normal transit fare, as shown in **Figure 11**.

5.3 Transit Demand by Fare Strategy

The ultimate goal of this research is to investigate how the existing transit passengers and non-transit passengers respond to the changes in fare policies in order that the policy makers can implement the most appropriate fare strategies that encourage more transit use but still maintain the satisfactory level of service. The researchers simulate the following hypothetic scenarios and analyses the corresponding effects:

Scenario A: A flat fare policy of 20, 25, 30, and 35 Baht

Scenario B: A common or rebated fare policy by reducing the total entry fee by 5, 10, and 15 Baht

Despite its simplicity, a disadvantage of flat fare policy is inequity, where short-distance travelers seem to subsidize the system operating cost for long-distance travelers who enjoy the relatively lower fare price. The common fare policy has different effects, while all transit demand group are equally offered the rebate amount of initial entry fee, the total transit demand will collectively increase. Whether the reduction in transit fare reduces the total fare revenue depends on price elasticity of demand as shown in **Tables 4-8**. If the level group is inelastic to price (**in bold**), reduction of fare price will reduce the total fare revenue and vice versa for the elastic demand group. The network capacity is also needed to be taken into consideration. For example, most of transit systems in Bangkok are operated with 4-car train. If the minimum headway is already achieved at present, the only approach to increase the line capacity is to lengthen the train set from 4-car into 6-car train which is equivalent to 50 percent increase in line capacity. Therefore, the common fare strategy will be most effective if majority of target groups are elastic to price but with changes in transit demand not exceeding reserve capacity (**as appear in thick boxes**).

Table 4: Changes in transit demand due to changes in fare policy by age group

Age	Flat Fare				Common Fare		
	20	25	30	35	-5	-10	-15
15-25	**-7%**	**-27%**	**-48%**	**-69%**	**21%**	**42%**	**62%**
26-35	23%	4%	-14%	-32%	18%	36%	54%
36-45	68%	32%	-4%	-40%	36%	72%	108%
46-60	107%	46%	-16%	-77%	61%	122%	183%

Table 5: Changes in transit demand due to changes in fare policy by distance traveled

Distance (km)	Flat Fare				Common Fare		
	20	25	30	35	-5	-10	-15
0-2	**-16%**	**-35%**	**-54%**	**-73%**	**19%**	**38%**	**57%**
2-4	**5%**	**-14%**	**-33%**	**-52%**	**19%**	**38%**	**57%**
4-6	**10%**	**-8%**	**-26%**	**-45%**	**18%**	**36%**	**55%**
6-8	39%	21%	3%	-15%	18%	36%	54%
8-10	49%	32%	16%	-1%	16%	33%	49%
10-12	**40%**	**22%**	**3%**	**-15%**	**18%**	**36%**	**55%**
12-14	52%	34%	16%	-2%	18%	36%	54%
14-16	**28%**	**4%**	**-20%**	**-44%**	**24%**	**48%**	**72%**
16-18	**9%**	**-9%**	**-27%**	**-45%**	**18%**	**36%**	**54%**
18-20	117%	100%	83%	67%	17%	33%	50%
20-22	187%	160%	133%	107%	27%	53%	80%

Table 6: Changes in transit demand due to changes in fare policy by income

Income	Flat Fare				Common Fare		
(USD/month)	20	25	30	35	-5	-10	-15
< 300	**15%**	**-2%**	**-19%**	**-36%**	**17%**	**34%**	**51%**
300-500	21%	1%	-19%	-39%	20%	40%	61%
500-700	**13%**	**-7%**	**-26%**	**-46%**	**20%**	**39%**	**59%**
700-900	28%	11%	-6%	-23%	17%	34%	51%
900-1,100	32%	16%	0%	-16%	16%	31%	47%
> 1,100	36%	9%	-19%	-46%	27%	54%	82%

Table 7: Changes in transit demand due to changes in fare policy by trip purpose

Trip	Flat Fare				Common Fare		
Purpose	20	25	30	35	-5	-10	-15
HBE	**-11%**	**-34%**	**-56%**	**-79%**	**23%**	**46%**	**69%**
HBW	25%	5%	-14%	-34%	20%	39%	59%
HBO	25%	8%	-8%	-24%	16%	32%	49%

Table 8: Changes in transit demand due to changes in fare policy by ticket type

Ticket	Flat Fare				Common Fare		
	20	25	30	35	-5	-10	-15
SJT	32%	14%	-4%	-22%	18%	36%	54%
Monthly Pass	**8%**	**-7%**	**-23%**	**-38%**	**15%**	**31%**	**46%**
SVT	12%	-7%	-27%	-47%	20%	39%	59%

6. CONCLUSIONS AND RECOMMENDATIONS

The old, long-distance, and high-income passengers have higher price elasticity of demand than the young, short-distance, and low-income passengers. The government policy of 20 Baht flat fare can attract more mass transit patrons and generate more revenue as most passengers are elastic to price. Despite advantage in higher revenue, the 20 Baht flat fare policy will make the system unnecessarily more crowded, discourage short-distance passengers (socially inequitable) and miss higher revenue that the government could earn from longer-distance trips. Therefore, the research outcomes recommend the optimal level of new rebated entry fee for common ticketing system that has the same impact on passengers' choice as that of the flat fare policy. The result shows that reduction of the entry fee by only 5 Baht per trips it will generate the same revenue as 25 Baht flat fare policy. At this fare level, the system can still encourage mass transit Patronage, maintain service quality (not too crowded), and sustain government or operators revenue. The outcome of this research could be useful for transit operators who might be interested to investigate the effects of new transit fare policies or strategies on the more dynamic transit demand and more complicated transit network in the future.

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