Article

COVID-19 Countermeasures and Passengers' Confidence of Urban Rail Travel in Bangkok

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Abstract: Rail transit systems around the world have been suffering from heavily reduced ridership due to reduced capacity for social distancing and passengers' concern over the risk of COVID-19 infection. Various countermeasures were implemented to reduce the COVID-19 risk so that passengers felt safe to travel on rail. The objectives of this study were to evaluate COVID-19 countermeasures of Bangkok's urban rail from passengers' viewpoints and examine its influence on passenger's confidence. The background of the COVID-19 pandemic in Thailand and the rail countermeasures implemented in Bangkok were summarized. The data were obtained from an interview survey of 1105 railway passengers conducted at the stations during the second wave of the pandemic. Factor analyses and structural equation modeling were conducted. The results revealed that social distancing was not satisfied by the passengers but adversely caused inconvenience and increased infection risk when the station or rail were congested. On the other hand, the passenger temperature check, face mask enforcement, and hand sanitization countermeasures were found to highly and positively contribute to passengers' confidence. Contact tracing application was also found to raise awareness and confidence. The findings provided insights for rail authorities and related agencies to effectively implement the countermeasures that would be practically and financially sustainable.

Keywords: coronavirus disease 2019 (COVID-19); pandemic; countermeasures; factor analysis; structural equation modeling; Bangkok urban railway

1. Introduction

The COVID-19 pandemic in Thailand is part of the worldwide pandemic of coronavirus disease 2019 (COVID-19) caused by severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2). As of 25 July 2021, the cumulative number of cases and deaths reported globally was almost 194 million and over 4 million, respectively [1]. Thailand was relatively successful in containing the pandemic throughout most of 2020. However, the situation became increasingly severe and uncontrolled since April 2021 until the time of writing this paper (June 2021). As a brief summary of the situation, the initial wave of infection started when the first known case arrived in January 2020. The peak was on 22 March 2020 when 188 newly confirmed cases were reported in a day [2]. In response to the first outbreak, effective on 26 March 2020, the prime minister declared a state of emergency while the Centre for COVID-19 Situation Administration (CCSA) was also established to coordinate the government's responses. Several countermeasures were implemented in varying degrees throughout the country, including temporary shutdown of portions of the public and private sectors, closing of the potential risk places, no activity in crowded places, and imposing a night curfew from 10 p.m. to 4 a.m. These measures were known as soft lockdown

while necessary activities and travels were still allowed but cooperation of people to work from home was requested. As people had cooperated quite well with countermeasures and advisories. The new infection cases had gradually dropped throughout April 2020. By the middle of May 2020, the local infection cases were reportedly approaching zero. The strategies that were considered to be highly effective included social distancing, face mask wearing, working from home, and staying home at night [3]. Restrictions were gradually released in various phases since 3 May 2020, starting with businesses with lower risks in a respective order. The night curfew was ended in July. Eventually, schools were fully reopened in August 2020, indicating that the outbreak was ending.

After a while, the second wave of infection hit Thailand in December 2020 when more than several hundreds of daily infection cases were detected, originated from a cluster of illegal immigrant workers in an industrial area outside Bangkok. The outbreak spread out the country rapidly. On 26 January 2021, the peak was reportedly 959 infection cases in a day [4]. Several countermeasures were implemented again but were less stringent than in the first wave. The situation partially subsided in February until the third wave hit in April 2021, originated from a cluster in entertainment venues in Bangkok. The outbreaks were rapid in Bangkok, as well as throughout the country, due to the beta and delta variants. New high records were marked repeatedly with more than 5000 new daily cases by the end of May 2021 [5]. The situation was so severe so that urban activities were much reduced, as did the travel demand in the urban area.

1.1. Urban Railway in Bangkok during the Pandemic

In Bangkok, Thailand's capital city with more than 10 million inhabitants, five urban railway lines have been operating, namely the dark-green line, the light-green line, the blue line, the purple line, and the airport rail link.

Before the pandemic, the total urban railway ridership was more than 1,275,000 person-trips/day. The total railway ridership reduced to 266,142 person-trips/day or 79% reduction during the first wave in April 2020. As for the blue line, the main circumferential line connecting with other lines carrying passenger from the outer residential areas into the city center, its weekday ridership decreased significantly during the three waves of infection, as shown in Figure 1. It is obvious that the ridership is highly correlated with the daily new infection case. For the first wave, the ridership dropped from 481,433 person-trips/day to 85,792 person-trips/day.

After the government had gradually eased the lockdown and restrictions since May 2020, urban activities continuously resumed, and the travel demand gradually increased both on private and public transport modes. The weekday ridership on the blue line train reached nearly 400,000 in December 2020. During the second wave, its weekday ridership dropped to 170,000 passenger-trips/day, but after a few weeks as the situation had gradually relieved, its weekday ridership recovered to more than 310,000 passenger-trips/day. During the third wave, which was more severe than the previous two waves, the overall urban travel demands had dropped to a similar level as it was in the first wave.
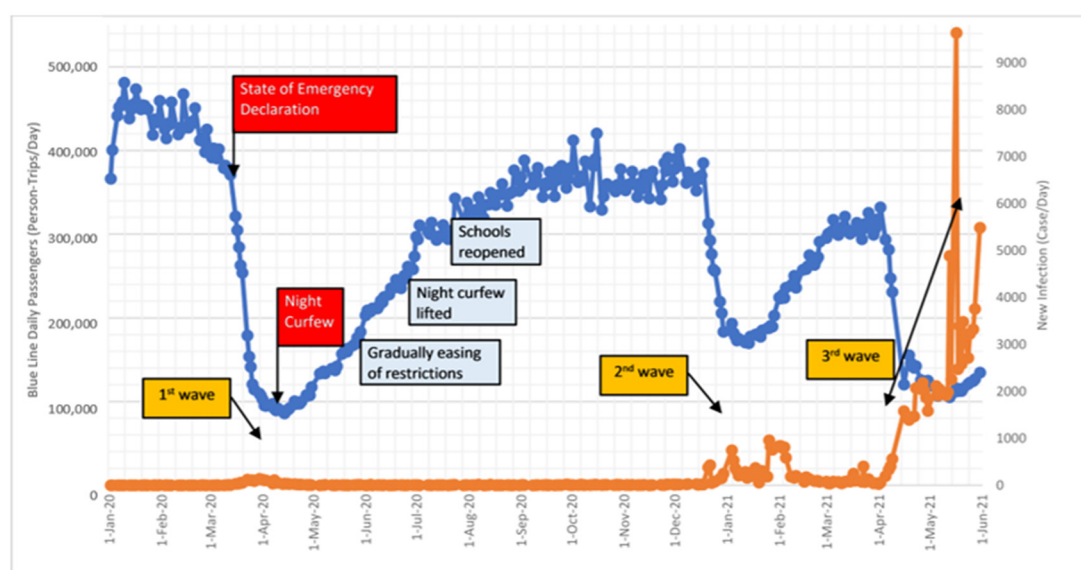
Figure 1. The blue line train's weekday ridership versus the new daily COVID-19 cases in Thailand. The first two waves of infection peaked in April 2020 and January 2021. The third wave of infection started in April 2021 while the new high records were reported repeatedly until the time of writing this article.

1.2. COVID-19 Countermeasures of Bangkok's Urban Rail

As for the blue line train, various countermeasures were implemented in the railway system ranging from temperature screening of passengers, social distancing, cleaning and disinfection of vehicle and facilities, and adjustments of staff management as well as train operations. To describe this in more detail, the temperature of passengers was checked at the security checkpoint before allowing them to enter the station (Figure 2a). Many passengers found it was very efficient in screening of infected or potentially infected persons, while some would like to know the value of their checked temperature as well as their surrounding passengers' temperature so that they would feel safer in the current trip. Although the temperature checks were performed automatically by using thermal cameras, at some stations the temperature checks were still performed manually by using handheld infrared thermometers. This had caused some concerns to some passengers as the staff would need to stand relatively close to them to take their temperature. Sanitary gels were provided for public use at various points around the station, including the security checkpoints, ticket booths, and platform area (Figure 2b). Importantly, all passengers were required to always wear face masks at all times they were at the station and on board the train, although the law had not yet required everyone to wear face mask during the first wave.

Several social distancing measures were enforced in the train system. Inside the train station, the number of passengers was limited to ensure there was adequate room for social distancing to be respected. One meter markers were placed on the floor in the queuing area to ensure social distancing. The queues were released by group of passengers, which was limited the platform capacity that was reduced by 50% of the normal capacity. However, on a typical day, passengers needed to wait in line in front of the station entrance. The average waiting time was around 10 min. However, it was more than 30 min in the peak hour (Figure 2c). At the platform, yellow markings on the floor required the limited number of passengers to stand 1-m away from each other while waiting for the approaching train (Figure 2d). The number of passengers allowed on platform was determined based on the real-time information of crowding of the train to come. On the train, social distancing practices were implemented (Figure 2e). The standing passengers were required to stand at the specified 1-m distancing marks and face a recommended direction. The seating passengers were allowed to sit on every other seat; the rest of the seats were blocked to prevent passengers seated directly beside others. These were very

effective in preventing transmission of the disease but heavily reduced the system capacity (approximately reduced by more than 80 percent). However, such a reduced capacity could not accommodate the recovering travel demand when the situations gradually improved. Social distancing measures had been becoming less practical and eventually not restricted when the train was congested. Later, alternate seats blocking was cancelled so that all seats were occupied fully.

Rail passengers were encouraged to use the mobile application, namely Thai Chana (literally means "Thais win" in Thai language) to check-in and check-out when they get on and get off the train. The app must be installed in their mobile phone. Check-in was conducted using the phone's camera to scan a QR code that was posted at many visible locations of the train such as the train's glass panel or side windows (Figure 2f). However, some passengers found it was inconvenient when the stickers were not available in hand-reachable range. Some felt it was impolite to hold a mobile phone over other passengers' head to reach the QR code sticker. Moreover, some feared they may look as if they were taking photos of other passengers without permission, which is illegal and subject to penalty by the law. In fact, the Thai Chana app was developed and generally used at public places such as shopping malls, restaurants, and other venues around the country. The customers and patrons were requested to check in and check out by using the app whenever they enter and leave a place. The visit information was centrally pooled at the ministry of public health and used to notify, via the app, persons after they had visited a place that might have risk of infection and prompt them to get COVID-19 test. Additionally, another mobile application, namely Mor Chana (literally means "doctor wins" in the Thai language), was later developed, allowing smartphone device users to conducted self-assessment and determine their level of infection risk based on their travel history and exposure to COVID-19. Use Mor Chana app in areas that had a high risk of infection was mandated, these being designated by the government as maximum and strict control zones. However, there were strong criticisms as the app potentially infringed personal information and raised privacy concerns.

Behind the scenes, the train operator had put large efforts for the cleaning operations, before and after the daily operations to ensure the hygiene of the system by disinfecting the train using disinfectant solution (Figure 2f left). During the operation, the train interior was disinfected (especially the contact surfaces) every time the train reached the last station. Moreover, the station facilities such as ticket vending machines, escalator handrails, guardrails, wicket gates, elevators, etc. (Figure 2f right) were cleaned and disinfected more frequently. These intensive cleaning and disinfection required three times the normal number of cleaning staffs, but this was worthwhile as passengers felt more confident when they observed cleaning and disinfection were undergoing.

In addition to those measures, the train operator had disseminated the necessary information and provide guidelines for passengers to travel safely or behave appropriately when using public transport. Various media and communication channels were employed such as posters, public announcement at stations and on board, social media, etc. These were especially useful for passengers during the beginning of implementation, as passengers were not aware of the new rules such as using face masks and refraining from talking. In addition, contactless payment methods were recommended, and cash payment was to be avoided. The train operations and staff management were also need adjustment to accommodate the social distancing implementation. Train frequency was increased during the peak hours to cope with the reduced capacity. However, the train frequency could not be increased much since the trains were already utilized at nearly full capacity while some trains were necessarily reserved for maintenance and in case of emergency.

Figure 2. COVID-19 countermeasures implemented for the blue line train. Courtesy of Mass Rapid Transit Authority of Thailand (MRTA). (**a**) Temperature check of every passenger by using thermal scan cameras and handheld infrared devices; (**b**) alcohol-based sanitizing gel supply at the security checkpoints and various place in the stations; (**c**) passengers queuing in front of the wicket gate. Social distancing was requested but difficult during peak hours; (**d**) limited number of passengers at the platform. Social distancing markers were placed on the floor; (**e**) reduced train capacity due to strict social-distancing measures: blocked seats and 1-m away standing; (**f**) contact tracing mobile application (app) for check-in and check-out when getting on and off the train; (**g**) daily train disinfection and frequent cleaning of station facilities: ticket machine, escalator handrails, etc.; (**h**) staff operation and management were adjusted to ensure maximum safety of the staffs.

For the staffs, COVID-19 countermeasures were rigorously implemented such as daily temperature check, face mask, medical glove, social distancing during work, etc. Remotely working from home was implemented as much as possible. For working on site, work hours were adjusted to enhance work flexibility. Staffs' rotation shifts were arranged so that the same group of staffs were doing work together in the same shift. If there was

a suspect of infection, that shift could be isolated and quarantined by not effecting the rest of the staff. This could largely reduce the risk of infection and ensure confidence and healthiness of staff members.

1.3. Objectives

As rail travel demand in Bangkok had dropped drastically during the COVID-19 pandemic, partly due to the reduced activities while some passengers were concerned of infection during the travel. Several countermeasures were implemented by the rail authorities, some of which had been positively perceived by the passengers while some had been negatively perceived and largely reduced the system capacity, meaning lower service levels and discouraging the use of rail. Thus, how effectively each of these measures could make passengers feel safe and travel with confidence were still questionable. The motivation was to seek for efficient COVID-19 policy measures that are complying with the public health standard and encouraging safe travel on rail. The research questions are: (1) how significant was each countermeasure as it was perceived by the passengers; and (2) what would be the effective countermeasures that contribute to passenger's confidence of rail travel against the perceived?

The objectives of this study were to evaluate the COVID-19 countermeasures from the passengers' viewpoints and determine its influence on passenger's confidence on rail. As a contribution of the study, the findings would provide insights for the rail authority and related agencies to effectively implement the forefront countermeasures as well as to prepare long term plans that would maintain the public transport as healthy and financially sustainable.

The overview of the study is shown in Figure 3. Firstly, literature reviews on the impact of COVID-19 on public transport and countermeasure implementation were conducted. Data collection consisted of questionnaire development, rail passenger interview survey at the stations, and data cleaning and processing. The data obtained from the survey was used in the three consecutive analyses: exploratory factor analysis, confirmatory factor analysis, and structural equation modeling. Finally, the findings were discussed and provided policy implications.
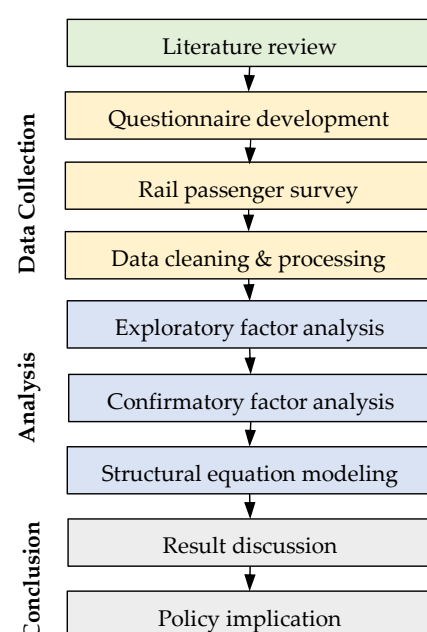
Figure 3. Flow of the study.

The paper is organized as follows. Section 2 summarizes the literature reviews on COVID-19 countermeasures, their impacts on public transport, and the analysis of

confidence of public transport. Section 3 describes the data collection and the data summary, and the analysis framework. Section 4 presents the results of the factor analyses and structural equation modeling. Section 5 discusses the findings, research contribution, and policy implications. Finally, the paper is concluded in Section 6.

2. Literature Reviews

2.1. Impact of COVID-19 on Public Transports

As a result of the lockdown and decreased activities, the demand of public transport around the world had drastically decreased since it was perceived as a risky place for COVID-19 infection, so passengers tried to avoid using it. For instance, in Santander, Spain, the public transport users decreased by 93% as a result of lockdown [6]. In Sweden, the public transport users decreased by nearly 60%, where most of the current users were found as captive riders [7]. In Hong Kong, China, the rail's commuting users on weekday decreased by 42% and the shopping users decreased by 42% and leisure users on weekend decreased by 81%, as a result of stay-home orders and travel restrictions [8]. In Taipei, Taiwan, the ridership of metro trips was decreased (especially at the stations associated with nighttime markets, shopping districts, schools and universities [9]). In Seoul, Korea, the subway ridership decreased substantially in late February but it had slowly recovered as the crisis has progressively relieved, indicating that people's perception on COVID-19 risk and adherence to social interaction has decreased [10].

As the situation developed and became less severe, the first lockdown was progressively relieved and the ridership gradually recovered to some amount. However, when the second lockdown was restricted, the ridership decreased again. In London, UK, the underground ridership reduced by 95% during the first lockdown and gradually recovered to 40% of normal. In the second lockdown, the ridership decreased again by 75% [11]. In Vienna, Austria and Oslo, Norway, the public transport ridership largely decreased during the two waves of the pandemic, however the impacts of the first wave were found to be stronger than the second wave (−80% vs. −60% for Vienna, and −70% vs. −60% in Oslo) [12].

In response to the decreased demand, the public transport operators needed to adjust their operation. In London, UK, the underground reduced its operating capacity but ensure sufficient capacity to allow for social distancing [11]. In Sweden, during the stay at home and work from home request, the public transport was operated at minimum levels to minimize the congestion and infection risks [7]. In Tampere, Finland, the bus frequencies were reduced, as bus ridership greatly decreased, but the service was kept at a sufficient level to meet the demand (although overcrowding were found during peak hours [13]).

In addition, the decreased public transport demand reflected a shift to other modes with lower perceived COVID-19 risk. An international comparative study found that modal shift from public transport to private car was found most remarkable in South Korea and China, a shift from to active transport modes were obvious in European countries, and a shift to motorcycle was large in India and other Asian countries [14].

2.2. COVID-19 Countermeasures on Public Transports

Various countermeasures were implemented to ensure that public transport was safe from COVID-19 [6–13,15,16]. Firstly, social distancing, referred as a practice of keeping distance of one to two meters away from other individuals, was commonly implemented both on board the transit vehicle, at stations or transit stops [14]. Inside the vehicle, it was common practice that alternate seats were blocked to keep passengers away from each other, such as in the UK [11], the United States and Canada [17,18], etc. Other implementations were variously found, e.g., bus drivers were separated from passenger with plastic sheet panels [11], one-way flow of passengers inside the train to prevent confronting of passengers [11], boarding bus from rear door only, etc. At the stations, to realize social distancing, restriction or limitation of passenger numbers in the system were implemented in many countries except for Japan and South Korea [14]. In some cities,

online advanced booking of public transport was implemented [14]. On the other hand, to relieve congestion under the reduced capacity, train cars were added [17,18].

Although face mask wearing was common practiced by passengers, it was a strict requirement in some cities. A study in Canada found that face mask mandatory had effectively reduced the COVID-19 transmission in public transport [19]. Monitoring of passengers' compliance with the countermeasure and their movement while using the public transport such as face mask wearing and passenger flow direction were conducted by employing innovative information technology, e.g., CCTV image recognition, mobile phone signal, credit card transaction, etc. [14]. Mobile application (known shortly as app) was widely developed for tracing of people's contact risk and identifying persons who may have high risk of infection. For instance, in Korea, a mobile application, namely Corona-100 m, alarmed users when they were within 100 m nearby confirmed patients [20].

Cleaning and sanitary countermeasures were commonly emphasized, especially with facilities, vehicles, and contact surfaces to ensure hygienic operation and services [12]. Handwashing by using hand sanitizer was encouraged, which was generally agreed to be a simple and effective in preventing from infection [21]. Other implementations included air ventilation enhancement by keeping windows opened during the train or bus operation [17,18]. Furthermore, those countermeasures were generally implemented in an integrated manner. For instance, integrated countermeasures of face mask wearing, cleaning and disinfection, health education, and adjusted train operation were every effective in China [22].

In terms of people's response to the countermeasures, different socio-economic groups of passengers had different behavioral responses. For instance, in Switzerland, young and healthy adults were found complying with social distancing very well [23], while in Seoul, Korea, young people were found having low awareness of social distancing in using subway while manufacturing workers were still travelling to work [10].

2.3. Analysis of Passengers' Confidence

Confidence of passengers was analyzed in the existing studies in various forms such as satisfaction or perception on safety to travel, confidence level to travel, willingness to travel, intention to travel, decision to travel, or mode choice. Several attributes were found to be influential to the confidence in varying degree, but mainly with respect to the countermeasures being implemented against COVID-19 infection risks and concerns, as summarized in Table 1. For example, passengers' satisfaction on public transport in China was found to be influenced by passengers' perceived safety, which was negatively affected by anxiety and psychological distance [24]; intentions of air travel to destinations with travel-bubble policy were negatively affected by such factors as concern of COVID-19, anxiety of the situation, and risk attitudes [25]; and public transport mode choice was largely influenced by the passenger's perceived safety. For instance, in India, it was positively affected by the social distancing measures, congestion management, and sanitizing frequency, and also significantly affected by age, gender, and occupation of the passengers [26]. Travel decision and mode choice for educational trip in an Italian university campus was found to be affected by that mode's attributes and the traveler's perception of risk on alternative modes implementing COVID-19 countermeasures, such as strict physical distancing, hand sanitizing gel supply, face mask usage, frequent vehicle sanitization, etc. [27]. Willingness of public transport travel in Gdansk, Poland was found to be affected by passenger's perceived safety on fear of infection risk, fear of vehicle disinfection, and fear of passenger's hygienic conformity [28]. Shift from public to private mode in India was found affected by the socioeconomic characteristics, travel time, overcrowding level, and hygienic standards [29]. Intention to use public transport in Lahore, Pakistan, was influenced by COVID-19 attitudes, awareness, responsibility, and difficulty of compliance to such measures such as hand sanitizing and face mask wearing [30]. Likewise, for air transportation, a study in Korea found that decision to make an air travel again after the COVID-19 pandemic subsides would be influenced by requirement for isolation and

quarantine at the destination, circumstances at the destination, social atmosphere with regards to overseas travel, and level of disinfection measures employed in the aviation service sector [31].

Table 1. Existing studies on travel confidence against COVID-19 concerns.

References	Confidence Construct	Influential Factors	Analysis Technique(s)
[24]	Public transport satisfaction	COVID-19 information attention, psychological distance, perceived safety of travel by public transport	Confirmatory factory analysis, structural equation model
[25]	Intention to travel to "travel bubble" destination	Fear of COVID-19, travel anxiety, risk attitude	Confirmatory factory analysis, structural equation model
[26]	Willingness to choose public transport mode	COVID-19 awareness, safety perception, attitude on public transport	Hybrid choice modeling
[27]	Decision to travel for educational and working trips	Socioeconomic characteristics, COVID-19 counter measures on each transport mode	Exploratory factor analysis, logistic regression analysis
[28]	Willingness to travel by public transport	Safety perception on infection risk, vehicle disinfection, hygienic conformity of other passengers	Descriptive statistics, chi-square test
[29]	Mode shift from public transport to car	Socioeconomic characteristics, travel time, overcrowding and hygiene levels	Logistic regression
[30]	Intention to use public transport	Socioeconomic characteristics, COVID-19 attitudes, awareness, responsibility, difficulty of adherence to the measures	Exploratory factor analysis, multiple regression analysis
[31]	Decision to resume air travel after COVID-19	Self-isolation, destination, social atmosphere of overseas travel, and disinfection measures	Confirmatory factory analysis, structural equation model

In these studies, the analysis techniques used were dependent on the purpose of the analysis as well as on the definition of the confidence of travel, ranging from descriptive statistics [28] to multivariate analyses [24–26,30,31] where exploratory factor analysis was used to discover the underlying structure of indicators of the constructs such as perceived safety with respect to several countermeasures. Confirmatory factor analysis was used to test the inter-relationship between the constructs while structural equation model (SEM) was employed to understand the causal effect on travel confidence [24,25,31]. For example, SEM were employed to analyze the compliance behavior with respect to social distancing measures in Switzerland where individual risk, household risk, social risk and gender were found significantly influential factors [23]. On the other hand, the decision behaviors were modelled based on dichotomous variable of choice by logistic regression [29] or hybrid choice model with latent constructs of safety perception [26].

Further than the rail passenger's confidence, SEM has been employed in the studies related to the COVID-19 pandemic. For instance, using SEM, changes in daily life of people in Japan were found to be associated with the communication of public information, individual's risk perception, and attitudes about policy-making [32]. The attitude towards COVID-19 vaccination among public health workers in New York was found to be highly affected by attitude toward vaccine and concerns of vaccine testing and approval [33]. Moreover, SEM has widely been employed for various instances regarding perception of public transport. For example, a study of cities in Sweden found that users' perceived accessibility was associated with public transport service quality, comfort, safety, and security [34]. A comparative study in Asian cities found that perception of local people on street design factors were influential to intention of transit walk, which would have significant roles to encourage active transportation during the COVID-19 pandemic including walk and bicycling [35].

3. Data and Methods

3.1. Rail Passengers Interview Survey

In this study, a face-to-face interview survey of urban railway passengers was conducted at ten stations of the blue and purple urban railway lines in Bangkok on the weekdays, from 28 January to 10 February 2021, which was during the peak of the second wave of the pandemic in Thailand. The survey consisted of three main parts: socioeconomic characteristics, travel behavior, and perception on rail's COVID-19 countermeasures.

The target groups were local passengers who usually traveled by rail before the pandemic, although their frequency of rail travel in a week may vary. 1105 passengers were randomly interviewed at the platform level while they were waiting for the arriving train. After data cleaning and processing, 1015 valid responses remained and were used for the subsequent analysis.

3.1.1. Profile of the Samples

The sample data (*n* = 1015) had fair distribution of personal and household characteristics. Gender mix was roughly comparable of male (43.6%) and female (56.4%). Age groups varied from young and middle-aged individuals to elderly persons. More than 80% had a university-level education. Most of the samples were working and had income of middle-level. Less than half were captive riders who did not have access to private vehicle, while the rest were choice travelers who had access to at least one private car or private motorcycle. The detailed distribution of the socio-economic characteristic is shown in Table 2.

Table 2. Socio-economic characteristics of the samples.

Characteristics		Frequency	Proportion
Gender	Male	443	43.6%
	Female	572	56.4%
Age	15–20	28	2.8%
	21–30	358	35.3%
	31–40	334	32.9%
	41–50	171	16.8%
	51–60	96	9.5%
	61–70	26	2.6%
	71–72	2	0.2%
Education level	Secondary school or below	17	1.7%
	High school, technical college	185	18.2%
	Bachelor's degree	749	73.8%
	Master's degree	64	6.3%
Occupation	Government officer	48	4.7%
	Company employee	659	64.9%
	Business owner	244	24.0%
	Student	52	5.1%
	Housewife	12	1.2%
Family size (persons)	1	34	3.3%
	2	332	32.7%
	3	330	32.5%
	4	209	20.6%
	>4	110	10.8%
Personal monthly income	≤10,000 Baht (≤$330)	34	3.2%
	10,001–20,000 Baht ($331–$660)	332	31.6%
	20,001–30,000 Baht ($661–$990)	330	31.4%
	30,001–40,000 Baht ($991–$1320)	209	19.9%
	40,000–50,000 Baht ($1321–$1650)	110	10.5%
	>50,000 Baht (>$1650)	36	3.4%
Number of cars available	0	371	36.6%
	1	606	59.7%
	>1	38	3.7%
Number of motorcycles available	0	440	43.3%
	1	554	54.6%
	>1	21	2.1%

3.1.2. Travel Behaviors before and during the Pandemic

As shown in Table 3, most of the samples were frequent users of the railways and were mainly going to/from work or school. Access/egress modes varied, many of them were public transport and paratransit such as bus, van, shuttle, taxi, motorcycle taxi, etc. More than 92% of the samples reduced travel on rail during the pandemic. The decrease of travel demands was due to the change of lifestyle and activities such as work or study from home. Many samples avoided travel by rail because they feared of infection risk during the travel on rail as well as during the travel to and/from station. Some changed mode because the travel time and/or costs of the alternative modes (bus, car) were faster or cheaper due to less traffic volume on the road.

Table 3. Travel behavior of the samples before and during the pandemic.

Travel Behaviors		Frequency	Proportion
Frequency of rail travel	Everyday	102	10.25%
	Mostly weekdays	675	66.49%
	Mostly weekends	135	13.26%
	Less frequent	104	10.00%
Trip purpose	Work	607	59.77%
	School/college/university	244	24.02%
	Business/work-related	83	8.14%
	Personal	59	5.79%
	Leisure	13	1.30%
	Others	10	0.98%
Access mode	Walk	190	18.70%
	Motorcycle taxi	267	26.26%
	Taxi	106	10.41%
	Bus/public van/shuttle bus	307	30.23%
	Private car	138	13.58%
	Others	8	0.82%
Change of rail travel due to the pandemic	Reduced rail travel	938	92.43%
	Increased rail travel	4	0.41%
	Travel by rail as before	73	7.16%
Reasons of reducing rail travel (multiple answers)	Work/study/activity from home	608	64.80%
	Fear of infection while travelling by train	420	44.77%
	Fear of infection while travel to/from station	305	32.52%
	Other modes are faster	291	30.98%
	Other modes are cheaper	91	9.65%
	Less social activities	59	6.24%

3.1.3. Perception on Rail's COVID-19 Countermeasures

Subjects were asked how much they agreed with each of the twenty-eight statements regarding COVID-19 countermeasures being implemented in the blue and purple line trains on a 7-point Likert scale: definitely agree = 7, agree = 6, somewhat agree = 5, neutral = 4, somewhat disagree = 3, disagree = 2, and definitely disagree =1 (Table 4). These values of 7 to 1 were transformed into values from 10 to 0 for easier interpretation in the table only; the original values were used in the subsequent analysis. The passengers' perception of each countermeasure was evaluated as how important the samples felt to implement each measure. The significance of countermeasure implementation was evaluated as if the samples were in a situation when such countermeasure was not successfully implemented and successful. The degree of contribution of each countermeasure on passenger's confidence was evaluated as if the countermeasures were fully conformed or properly implemented. It was found that perception of health and sanitary-related countermeasure items such as temperature check (1), hand sanitizing (1), face mask (1), or facility cleaning (1) are high (average > 8.5); while perception on social distancing measures (Block alternate seat (1),

1-m distancing (1), and limited capacity (1) are relatively high (average > 7). It was found that awareness against infection risks (items 11 to 19) vary considerably. On the other hand, all of the countermeasures have relatively high contribution to safety feeling, as the mean value of the item 20 to 28 are relatively high. More detail on frequency distribution of the evaluation is shown in Figure 4. It was noticed that distributions of the values vary across the items. Four countermeasures that have very high scores (sum of 6 and 7 is greater than 90%) were temperature check, face mask, hand sanitizing, and facility cleaning.

Table 4. Perception of the COVID-19 countermeasures. Subjects were asked how much they agreed with each of these twenty-eight statements on 7-point Likert scale (definitely agree = 7, agree = 6, somewhat agree = 5, neutral = 4, somewhat disagree = 3, disagree = 2, and definitely disagree = 1). The values of 7 to 1 were transformed such that minimum = 0, maximum = 10, average = 5 for ease of interpretation in this table only; the original values on the 7-scale were used in the subsequent analysis.

| No.	Variables	Statements Regarding the COVID-19 Countermeasures	Average
1	Block alternate seat (1)	It is important to block every other seat.	7.42
2	1-m distancing (1)	It is important to keep 1-m distancing at the station and on the train.	7.20
3	Limited capacity (1)	It is important to limit the number of passengers at the station and on the train.	7.52
4	Temperature check (1)	It is important to check the temperature of passengers before entering the station.	9.07
5	Hand sanitizing (1)	It is important to use hand sanitizer before and after travel.	8.98
6	Face mask (1)	It is important to wear facemask at the station and on the train.	9.33
7	No-talk (1)	It is important to refrain from talking while on board the train.	8.22
8	App (1)	It is important to check-in & -out the train with app when getting on & off.	5.93
9	Facility cleaning (1)	It is important to clean and disinfect the train and station facilities frequently.	9.37
10	Station crowded	I feel worried when the station is crowded.	7.55
11	Train crowded	I feel worried when the train is crowded.	6.18
12	Stand near	I feel worried when someone stand near me on the train.	7.27
13	Sit near	I feel worried when someone sit next to me on the train.	6.78
14	Temperature check (2)	I feel worried when the passenger temperature is not checked before entering.	5.78
15	Hand sanitizing (2)	I feel worried when passengers do not sanitize hands before and after the travel.	8.52
16	Face mask (2)	I feel worried when other passengers do not wear face mask.	9.32
17	No-talk (2)	I feel worried when passengers talk while on board the train	8.57
18	App (2)	I feel worried when passengers do not check-in and -out the train with app.	8.07
19	Facility cleaning (2)	I feel worried when train and station facility cleaning operations are not seen.	9.10
20	Block alternate seat (2)	I feel safe when alternate seats are blocked.	7.70
21	1-m distancing (2)	I feel safe when passengers keep 1-m distancing while standing.	8.32
22	Limited capacity (2)	I feel safe when the station and train are controlled not to be crowded.	6.78
23	Temperature check (3)	I feel safe when the passenger temperature is checked before entering.	7.90
24	Hand sanitizing (3)	I feel safe when passengers use hand sanitizer before and after the travel	8.37
25	Face mask (3)	I feel safe when every passenger wear face mask.	7.80
26	No-talk (3)	I feel safe when no passenger is talking on board the train.	8.05
27	App (3)	I feel safe when passengers do check-in &-out with app when getting on & off.	6.98
28	Facility cleaning (3)	I feel safe when the train and station are disinfected every half an hour.	8.82
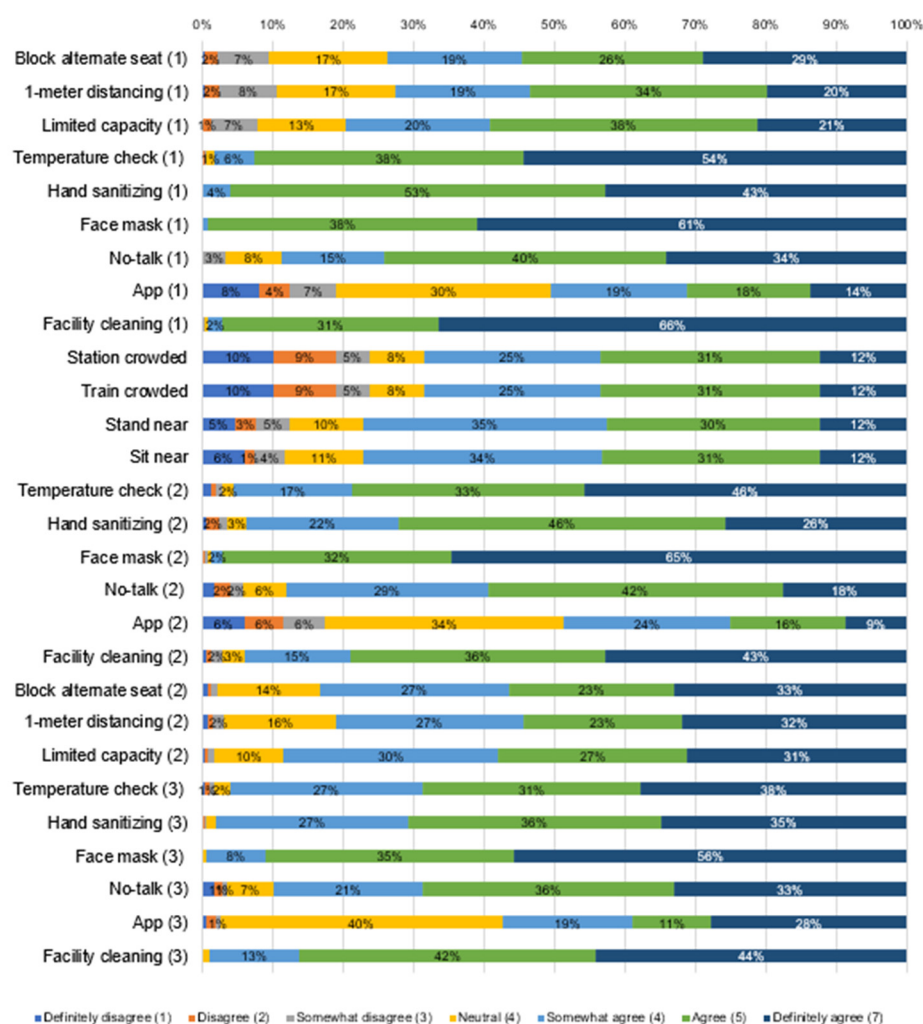
Figure 4. Perception and evaluation on rail's COVID-19 countermeasures.

3.2. Analysis

By using the data obtained from the passenger interview survey, the following analyses were conducted. Firstly, an exploratory factor analysis (EFA) was conducted with principal component extraction and varimax factor rotation by using IBM SPSS Statistics 27. The maximum likelihood parameter estimation technique was employed. The estimated factor loadings of the items allowed to understand the underlying structure of the factors. Factor loading value of 0.30 to 0.40 was considered acceptable for interpretation, value of 0.50 or larger was practically significant, value 0.70 or larger indicated a good structure; while the cross-loading items were eliminated [36]. The Kaiser–Meyer–Olkin (KMO) value (>0.8) and Bartlett's test of sphericity (*p*-value < 0.05) were determined to test the appropriateness of the analysis; while the Cronbach's alpha (>0.7) was calculated to evaluate the scale reliability [36].

Secondly, a confirmatory factor analysis (CFA) was conducted by using IBM SPSS AMOS 27 to validate the measurement models of the latent constructs that were identified through EFA. To test the reliability of the constructs, Construct reliability (>0.7) and Average Variance Extracted (AVE) (>0.5) were determined [36,37]. Thirdly, a structural equation model (SEM) was analyzed to examine the causal effects among the latent constructs by emloying IBM SPSS AMOS 27. The model fit was evaluated and the goodness-of-fit statistics and indices were presented: model Chi-square (χ^2), Goodness-of-Fit Index (GFI)(>0.9), Comparative Fit Index (CFI) (>0.9), the Steiger-Lind Root Mean Square Error of Approximation (RMSEA)(<0.08), as recommended in [36,37]. As Chi-squared test is biased

to sample size, the normed Chi-square, as a ratio of Chi-square to the degree of freedom (CMIN/df) was determined (<5.0).

4. Results

4.1. Factor Analyses

The exploratory factor analysis (EFA) on 28 measurement items with Varimax rotation extracted 5 factors, accounting for 76.811% of the total variances. The KMO value was 0.919 (>0.8) and the Chi-square value in Bartlett's test of sphericity χ^2 (df = 190) was 16,620.10, significant at $p = 0.000$, indicating that the data was suitable for the factor analysis. The varimax standardized factor loadings of each measurement item and Cronbach's alpha of each latent construct are shown in Table 5. All items underlying each of these five factors were significant, having factor loading values above 0.50 as practical cut-off while many having value above 0.7, indicating a good structure. The values of Cronbach's alpha were well above 0.5, indicating reliable scales.

Table 5. Explanatory factor analysis results. Factor loadings below 0.30 are not shown and cross-loading items are omitted. Scale reliability of the latent construct is shown by Cronbach's alpha.

Latent Construct	Measurement Items	Factor					Cronbach's Alpha
		1	2	3	4	5	
Confidence	1-m distancing (2)	0.843					0.935
	Block alternate seat (2)	0.808					
	Limited capacity (2)	0.830					
	Temperature check (2)	0.767					
	App (3)	0.786					
	No-talk (3)	0.750					
	Hand sanitizing (3)	0.770					
Awareness	Station crowded		0.648				0.922
	Stand near		0.908				
	Train crowded		0.824				
	Sit near		0.888				
Distancing measures	Block alternate seat (1)			0.950			0.949
	1-m distancing (1)			0.936			
	Limited capacity (1)			0.896			
Health measures	Temperature check (1)				0.649		0.735
	Hand sanitizing (1)				0.647		
	Face mask (1)				0.717		
	Face mask (2)				0.686		
Contact tracing app	App (1)					0.869	0.780
	App (2)					0.751	

The first factor consisted of seven items indicating passenger's feeling of safety with implementation of each countermeasure and was named as Confidence. The confidence of passenger to travel was similarly presented as perceived safety [24], travel intention [25], or travel mode choice [26,27]. The second factor, named as Awareness, consisted of four items indicating feeling of worry against each COVID-19 risky condition, representing passenger's concern of negative consequence. It was variously represented in the literatures (for instance, as attitudes of travel against risk on public transport [30], as psychological distance over COVID-19 seriousness on public transport [24], as people's knowledge about the pandemic situation being influential to one's mode choice [26] or as anxiety of travelling to any destination involving different risk and uncertainty [25]). The last three factors, consisted of the measurement items associated with passenger's perception on significance of countermeasures, were named as Distancing measures, Health measures, and Contact tracing app, respectively. The user's perceptions on COVID-19 countermeasures were similarly represented in the literatures. For instance, as safety perceptions over crowd

management and social distancing [26], as perception of countermeasures implementation on alternative transport modes influencing mode choices [27], or as perception on aircraft disinfection countermeasure influencing air travel decision [31].

A confirmatory factory analysis (CFA) was conducted and confirmed the measurement models derived from the EFA results. The validity of the constructs is shown in Table 6. Most of the indicator values were acceptable. Construct reliability > 0.7 and AVE > 0.5, although the AVE of Health measures was marginal, but the factor was kept for interpretability of the result. These constructs were used for the subsequent SEM analysis.

Table 6. Validity of the latent constructs.

Latent Constructs	Construct Reliability	Average Variance Extracted (AVE)
Distancing measures	0.951	0.865
Contact tracing app	0.796	0.664
Health measures	0.736	0.415
Awareness	0.876	0.641
Confidence	0.936	0.679

4.2. Structural Equation Modeling

Based on the CFA result, a SEM model was developed in which the structural model examined the influential relationship among the rail's COVID-19 countermeasures, awareness of passengers, and passenger's confidence of rail use. The result of the maximum likelihood estimation is presented in Figure 5, where the standardized values of the factor loadings and path coefficients are shown.
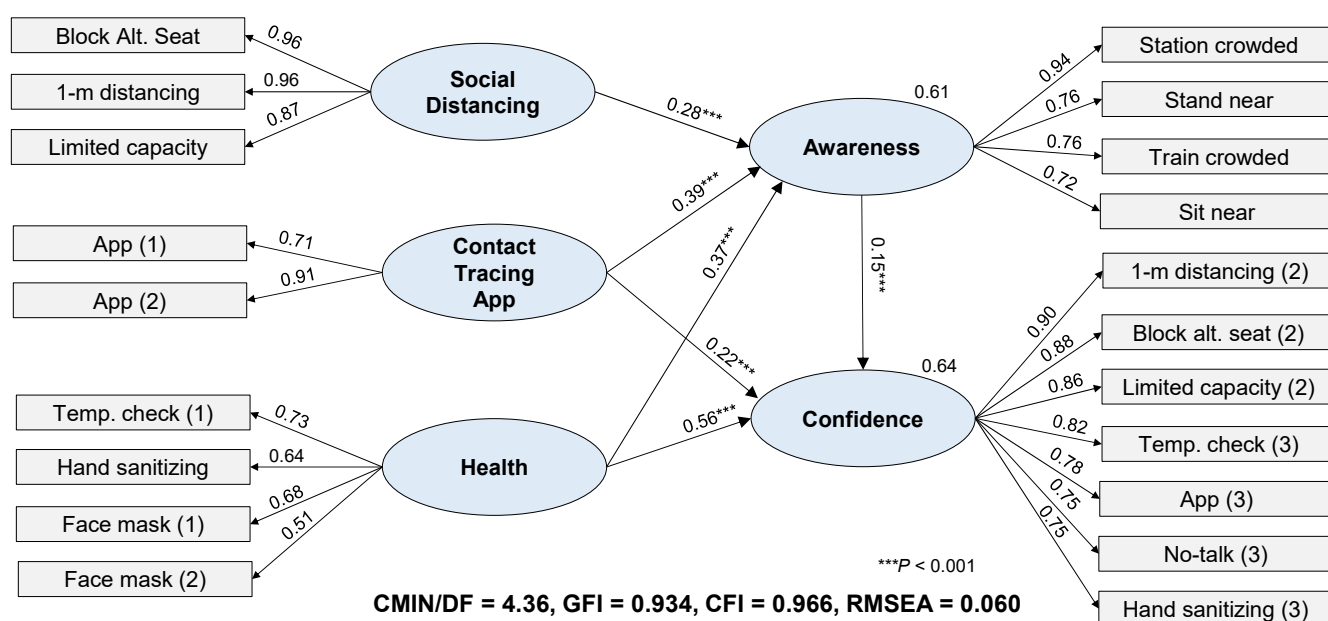
Figure 5. Structural equation modeling results.

The model result was acceptable as all model parameters were statistically significant. The model fit indicators, such as the normed Chi-square CMIN/df = 4.635 (<5), GFI = 0.934 (>0.9), CFI = 0.966 (>0.9), and RMSEA = 0.060 (<0.08) were within the acceptable range [36]. The path coefficients were statistically significant with $p < 0.001$. The model accounted for 61% of variance in Awareness and 64% of variance in Confidence. The structural model results revealed that different countermeasures had influence on Awareness and Confidence at different degrees. Social distancing countermeasures had influence on Awareness (direct, 0.28) and on Confidence through Awareness (indirect effect 0.04 = 0.28 × 0.15). The contact tracing app had an influence on Awareness (direct effect 0.39) and Confidence

(total effect 0.28 = direct 0.22 + indirect 0.39 × 0.15). Health-related countermeasures had influence on Awareness (direct effect = 0.37) and Confidence (total effect 0.62 = direct effect 0.56 + indirect 0.37 × 0.15).

These findings were supported by the literatures. Confidence of travel or satisfaction on public transport were also found to be positively affected by perception of safety as in [24] or by perception of countermeasure implementations such as social distancing, face mask, hand sanitization, or vehicle disinfection as reported in [26–31]. On the other hand, confidence was also found to be negatively influenced by traveler's anxiety over perceived COVID-19 risk as reported in [24,25,30]. Awareness had significant influence on travel confidence as reported in [29]. Additionally, this study innovatively found that contact tracing app had a positive influence on awareness of COVID-19 risk and positively contributed to confidence of rail travel.

5. Discussion

5.1. Passengers' Perception of the Countermeasures

Based on the users' perception survey and the analysis results, this study empirically found that confidence on rail travel could be attributed to the implementation of COVID-19 countermeasures at different extents. Firstly, it was found that the most effective countermeasures were related to public health and hygiene, including passenger's temperature screening, enforcement of face mask use, and supply of hand sanitizers. These measures were highly evaluated because they were convenient to passengers and apparently related to cleanliness and healthiness. Secondly, contact tracing apps were found to be effective in raising passengers' awareness of COVID-19 and indirectly contributed to raising passengers' confidence. On the contrary, this study found that social distancing measures were less influential to raise the passengers' confidence and conversely produced negative outcomes to public transport. Although social distancing was found to be very successful in reducing the COVID-19 infection risk and recommended for implementation in the public space [3]. It consequentially reduced the rail's ridership, as previously reported in [7–12]. It was therefore judged not financially sustainable from the viewpoint of railway operators, as rail transit normally need many passengers.

In addition, the limitation of system capacity caused huge inconveniences, as passengers were kept waiting before being allowed to pass the wicket gate, go to the platform, and wait for the train. In the queue, although social distancing was requested, it was difficult due to limited space inside the station, making the measure less practical. On the other hand, the congested queue increased risk of transmission of the disease. Moreover, the total travel time drastically increased and was sometimes uncertain, indicating severely decreased service levels. Such unfavored travel experience made the rail less attractive. Passengers who had alternative, choice riders would change to travel by car, although passengers who did not have car would still need to travel on public transport despite infection concerns. This would, in turn, become an equity issue. Therefore, even under with COVID-19 circumstances, we need a public transport system that is financially feasible, solves traffic congestion, provides accessibility for all groups of people in the society, but does not put burden on the environment, as similarly addressed in [11]. The countermeasures must be properly implemented and well perceived by the passenger such as vehicle cleanliness and hygiene and vehicle occupancy, as address in [6]. The findings in this study are in line with [15]; rather than physical distancing, which challenges the concept of mass transportation, the proper use of facemasks would also significantly reduce the probability of infection.

5.2. Policy Implications

5.2.1. Plausible Countermeasures

Based on the findings, physical social distancing in public transport was not largely contributing to raise passenger's confidence, but it reduced the system capacity and the service level, and thereby negatively affected the rail travel demand. The decreased

ridership would lead to deficits and require financial support. This was evident, for example, in the UK, where the public financial support was provided to maintain the rail services during largely decreased ridership and implementation of social distancing [11]. In Sweden, public transportation received a support from the government of approximately 300 million USD [7]. Therefore, well integrated implementation of such countermeasures as temperature screening of passengers, wearing face masks, refraining from talking, and contact tracing apps would be as equivalently efficient as social distancing implementation in preventing COVID-19 transmission, but not as much in compromising with passenger convenience. In addition, the contact tracing app should have more functionality to notify the users of risky condition and should be more convenient to use. For instance, QR-code check-in and check-out may be replaced by automatic detection by Bluetooth or Wi-Fi communications (although privacy concern must be addressed properly).

5.2.2. Spreading the Peak Demand

As social distancing was practically difficult, reducing the peak demand in rush hours would help to prevent crowding in the system. In the short term, as a physical distancing measure, transport demand management should be properly implemented such as demand redistribution to avoid rush hours (as also recommended in [6,14]). Flexible working hours would also help to reduce COVID-19 risk during the commute, as similarly suggested in [8]. In Bangkok, where the lockdown was not fully restricted, and people were still allowed to travel for work and conduct essential activities in the daytime, the number of rail passengers was not very low. It would be necessary to manage the public transport demand so that the system could accommodate the demand within the reduced capacity. The management could be exercised at different restriction degree. For instance, in New Zealand, strict measures were implemented to allow only essential workers on public transport [38]. In Japan, softer measures were implemented through social campaign targeting to groups of people rather than individuals, aiming to reduce non-essential travels [39].

In the long term, a change in lifestyle will be obvious. For instance, online working at home, at satellite office, at cafe, etc. will become more popular; car dependence will become more obvious as people will avoid traveling on crowded and COVID-19 risky public transport; and some people would leave from the city centers and live in a lower density neighborhoods [14]. This study recommends considering policy for a systematic behavioral change of people with proper travel demand management. Otherwise, car traffic would rapidly resume, and congestion would be even more severe. Such new normal lifestyle as flexible worktime or flexible workplace would help reducing congestion on road and on public transport and simultaneously increase the quality of human well-being or quality of life (QoL), as much discussed in [40–42].

5.2.3. COVID-19 Safe Transit-Oriented Development

As most of the rail users in developing countries are low-and-middle-income people, who do not have access to car and are captive to public transport (apparent in the samples in Table 2), the transit-oriented development needs city-planning interventions, such as promotion of transit use and control of car use [43]. Even in the COVID-19 pandemic, the authority must secure public transport system for keeping trust and confidence of people, in which proper countermeasures should be taken to avoid more dependence on car use, similarly discussed in [14].

During COVID-19, it was obvious in many cities that public transport users decreased while car traffic increased. This was due to people's concern of the COVID-19 risk. This study found that passengers were afraid of COVID-19, not only while traveling on the rail but also during access and egress (Table 3). In the developing countries, access to the station is generally not good. In Bangkok, the popular mode of access is motorcycle taxi, in which the risk of COVID-19 is very high since the passenger need to sit very close to the driver. Such poor access modes effectively discourage the use of the main public transport

mode. Therefore, rail countermeasures alone are not a solution, but an integrated system of measures needs to be considered where all other public transport modes must also be safe and get promoted. This was also similarly proposed in the UK, where long-term policy for integrated multi-transport modes will be necessary, particularly for commuting trips [11]. In addition, active transportation would need to be promoted as a safe station access mode, so walkable cities with infrastructure for active transport should be realized, as also recommended in [44]; for example, in the UK, large investment for reallocation of space for walk and cycling on road were required [11]. However, in developing countries, the walking environment is not good and not encouraging people to walk [35,45,46], research and study related to improvement of the walkway and walking environment need urgent attention.

5.2.4. Healthy Mobility-as-a-Service (Maas)

Recently, mobility-as-a-service (Maas), its definition and applications recently reviewed in [47], conceptually integrates transport modes and payment so that more efficient use of existing transport infrastructure can be expected, which in turn benefit both public authorities and private companies. MaaS operators matches demand and supply of various transport models and tries to optimize the efficiency of the whole system. In addition to the increased service quality brought by seamless transport modes, MaaS may also play important role as COVID-19 responses in various aspects. MaaS will enable passenger to access to the detailed real-time information on relative safety or risk of alternative trips (e.g., crowding levels, time-in-transit and frequency of cleaning) and make proper decisions to travel [48]. Despite the privacy concerns, such information of passengers as vaccination record, infection risk, movement trace, etc., may be stored and shared to the related parties and used to optimize the transit system performance, such as frequency adjustment to reduce congestion on vehicle. Moreover, on the supply side, thanks to single payment on MaaS platform, transit operators can adjust the fare level in response to the real-time traffic information, and offer discounts for travel during non-peak periods to spread the demand out of the peak hours.

6. Conclusions

Rail transit around the world has been suffering from reduced ridership due to the COVID-19 concerns of passengers and the resulting lower service level. Ranges of soft and hard countermeasures were implemented such as cleaning and disinfection, screening of risky passengers, contact tracing of passengers, reducing system capacity to realize physical social distancing, or managing the travel demand by advanced booking, etc. This study empirically examined the effectiveness of the countermeasures implemented of the blue and purple railway lines in Bangkok. It was revealed from the interview survey that passengers found the countermeasure implementation significant, especially face mask and hygienic measures such as hand sanitization and facility disinfection. The factor analyses and structural equation model revealed the effectiveness of countermeasures in association with the confidence of passengers of rail use. Social distancing was not appreciated by the passengers as it created large inconvenience and increased infection risk, and so did not directly contribute to overall confidence. However, it positively raised the awareness of passengers, and thus indirectly contributed to confidence. On the other hand, such countermeasures as passenger's temperature check, face mask enforcement, and hand sanitization supply were found to directly and highly influence confidence as well as awareness. Innovatively, this study found that contact tracing app contributed to positively raising awareness and user's confidence.

The findings of this study provided insights for the rail authority and the related agencies to effectively implement the forefront countermeasures in the short term, such as peak demand management aiming at more practical social distancing in the rail system. In the long term, it was recommended that they plan for more efficiently integrated public transport modes with active transportation. A structural change of lifestyle, both temporal

and spatial, would help reducing risky travel and reducing congestion. New technology would play important role for the changing lifestyle (e.g., Mobility-as-a-Service (MaaS) would help people to choose low-risk public transport routes and help operators to manage the system optimally).

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