Investigation on Physical Distancing Measures for COVID-19 Mitigation of Rail Operation in Bangkok, Thailand

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Abstract

The COVID-19 pandemic is the global health crisis and was declared a pandemic on 11th April 2020 by the World Health Organization (WHO). The most common solution is physical distancing which refers to avoiding close contact with other people by keeping a physical space between others. The COVID-19 pandemic is challenging mass transit services which are usually crowded with passengers. There is a need for an effort to save lives and stop spreading the virus, but metro transit still needs to provide services to people. Although the metro operators in Bangkok had a quick response to this pandemic by implementing physical distancing measures at stations and in passenger cars, effective levels of these measures are still under question. This study compares the physical distancing data surveyed during the COVID-19 pandemic and close contact transmission by breathing which defined the risk distance. The study investigates passenger levels of infection risk from close contact transmissions by breathing during the time at the metro station, based on the location where activities take place in metro stations: concourse level, platform level, and in the passenger car during the commute. The results show the risks of infection at metro stations and for passengers compared between the three metro operators in Bangkok city: Bangkok Mass Transit System (BTS), Metropolitan Rapid Transit (MRT), and Airport Rail Link (ARL).

Keywords: COVID-19 Pandemic, metro operation, physical distancing, public transportation, risk of virus transmission

1. Introduction

The novel coronavirus or COVID-19 is a pandemic of a coronavirus disease. The World Health Organization (WHO) first declared an outbreak on January 2020 and then the virus quickly developed into a pandemic by 11 March 2020. The COVID-19 disease spreads through droplets and aerosol which cause a high risk of infection on metro transit which is usually crowded with passengers throughout the day. Due to the large capacity of mass transit, the close contact conditions are difficult to avoid. Metro transit has a big role in controlling the spread of COVID-19 due to the objective of metro operations that transport large numbers of passengers within urban and suburban areas, as well as connecting to other modes of public transportation. Therefore, metro transit has a significant impact on spreading the coronavirus during pandemic if there are no safety measures implemented. Metro operators in Bangkok determined the infection prevention measures according to the recommendation from department of disease control which is a government organization under the ministry of public health. Department of disease control advocated one to two meters for a physical distancing between people in public places. However, there are differences on the interpretation of length of physical distancing in each metro operators.

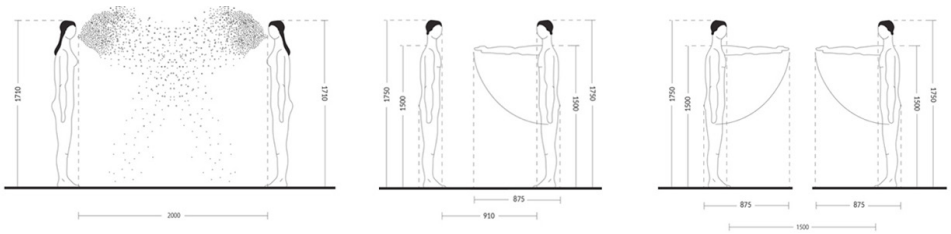
In Bangkok, metro transit (including Bangkok Transit System (BTS), Metropolitan Rapid Transit (MRT), and Airport Rail Link (ARL)) takes 55.73 % of the mode share of public transportation journeys (Mass Rapid Transit Authority of Thailand, 2018).Therefore, the metro operators in Bangkok responded promptly by releasing a safety protocol since the early stages of the global pandemic to help stop virus transmission and to protect passengers from illness. The preventive measures for COVID-19 in metro operation commonly refer to two major methods. First is the practice of good hygiene, on parts of the body especially on hands using the facilities provided in the metro operation to ensure virus-free conditions and reduce the risk of virus transmission. Second is physical distancing for maintaining physical space between other passengers and station staff during the commute. Due to unclear standards of physical distancing implementation for metro operation, the performance of physical distancing measures of metro operators in Bangkok is addressed in this study to observe the risk of passenger infection.

2. Literature review

Metro operators around the world rolled out measures to help stop spreading the virus during the COVID-19 pandemic. The aims of COVID-19 mitigation are to restrict numbers traveling and to avoid close contact to another passengers (Vos, 2020). Service reductions and weekend schedule adjustment (Washington Metropolitan Area Transit Authority, 2020) were introduced for reducing frequencies of metro service. These measures were implemented along with the maximum length of passenger car operation (Sound Transit, 2020). Service suspensions should also be considered for mitigating the COVID-19 transmission during the urgent phase (Zhang & Qian, 2020). According to (UK Department of Transport, 2020) on the guidance for using public transport during the spreading of COVID-19 were encouraged passengers to travel for only essential trips. The limited travel demanded by implementing social distancing, such as closures of certain businesses and venues may assist the effectiveness of public transport service suspension and help stop the distribution of COVID-19.

The most common safety measure in metro operation is physical distancing. Physical distancing (Kerkhove, 2020) (Lancker & Parolin, 2020) is a method to stop COVID-19 transmission due to the physical disconnection by keeping a distance that is safe enough to prevent close contact transmission from another people. Metro operators in Bangkok implemented physical distancing according the safety measures released by (Mass Rapid Transit Authority of Thailand , 2020). The point key of implementation is to keep an one to two meter distance between passengers by indicating a marker at facilities throughout the station area and using methods in the passenger cars for reducing seat numbers as well as capacity.

COVID-19 is transmitted mainly from person to person through several methods such as droplets from coughing, sneezing, and talking before developing into community spread. (Jones, 2020) illustrated, dimensions of different body positions in Figure 1., showing that droplets from coughing may travel 2 meters, the distance during general conversation between 2 people may spread 0.875 to 1.5 meter.



(a) coughed droplets distance (b) close conversation distance (c) far conversation distance

Figure 1. Physical distancing between people (Source: Jones, 2020)

Thisisrelatedtothestudyof(Liuetal.,2016) that presented the risk of disease spread by short-range airborne transmission through exhaled droplets between source manikins. The results show that high risk of transmission by normal breathing is within 1.5 meters between people, which is similar to the physical distance suggested by (Kowalski & Bahnfleth, 1998).

The metro services in Bangkok requires all passengers to wear protective masks at all times in the station and during the commute to limit the spread of certain respiratory viral diseases following (World Health Organization, 2020) suggestions on adapting mask-wearing together with physical distance measures to provide an adequate level of protection for COVID-19. To assist the efficiency of mask wearing, the empirical research of (Jung et al., 2014) suggested the penetration value of several protective masks. The most common masks, N95, surgical mask, and cotton masks, indicated 95%, 40%, and 30% effectiveness.

3. Methodology

The physical distancing measures of metro operators in Bangkok, were defined following the levels of operation areas at metro stations to identify the passenger risk of COVID-19 infection while using metro service. This study compares the physical distancing data that were surveyed during the COVID-19 pandemic and the close contact transmission by breathing which defined the risk distance according to (Liu et al., 2016) and also the risk level in the case of passengers wearing protective face masks regard the study of (Jung et al., 2014).

4. Level of physical distancing mitigation of metro transit during COVID-19

Several mitigations are conducted during COVID-19 for minimizing the risk of infection during commuting via public transport, such as social distancing, quarantine, self-isolation. The most obvious and practical method is found in social distancing mitigation that increases physical space between people to avoid spreading illness (American Red Cross, 2020). Therefore, this study classified the level of social distancing mitigation related to metro services in Bangkok into three levels: Macro, Meso, and Micro level, which interpreted the details as shown in Table 1.

5. Study areas

The data collection was conducted in 13 stations from all the metro operators in Bangkok city (Figure 2) located on four major lines: Sukhumvit line, Silom line, Chaloem-Ratchamongkhon Line, and City line for Suvarnabhumi airport. The observed stations were selected to represent two characteristics: interchange station and non-interchange from each major line. The interchange stations included Siam Station, Phayathai Station (BTS), Phayathai Station (ARL), Saladang Station, Asok Station, Silom Station, Bangwa Station (BTS), Bangwa Station (MRT), Sukhumvit Station. And non-interchange stations were Surasak Station, Bangna Station, Ratchadapisek Station, and Ramkhamhaeng Station.

Level	Explanation	Decision maker
Macro	Associate with the decision of using metro transit. According to social distancing policy that aims to reduce opportunity to access metro service in preference to provide a better choice not to commute using public transport which may increase the risk of infection during the pandemic.	-Central government -Local government -Company -Institution
Meso	Associate to a protocol of metro operation that adopts a mandatory social distancing policy through physical structures in metro operations during the pandemic.	-Metro operator
Micro	Associate to personal practices in both metro service employees and passengers for making an effort to keep a physical distance between people.	-Metro operator -Passenger

Table 1. Level of COVID-19 mitigation that associate to metro services

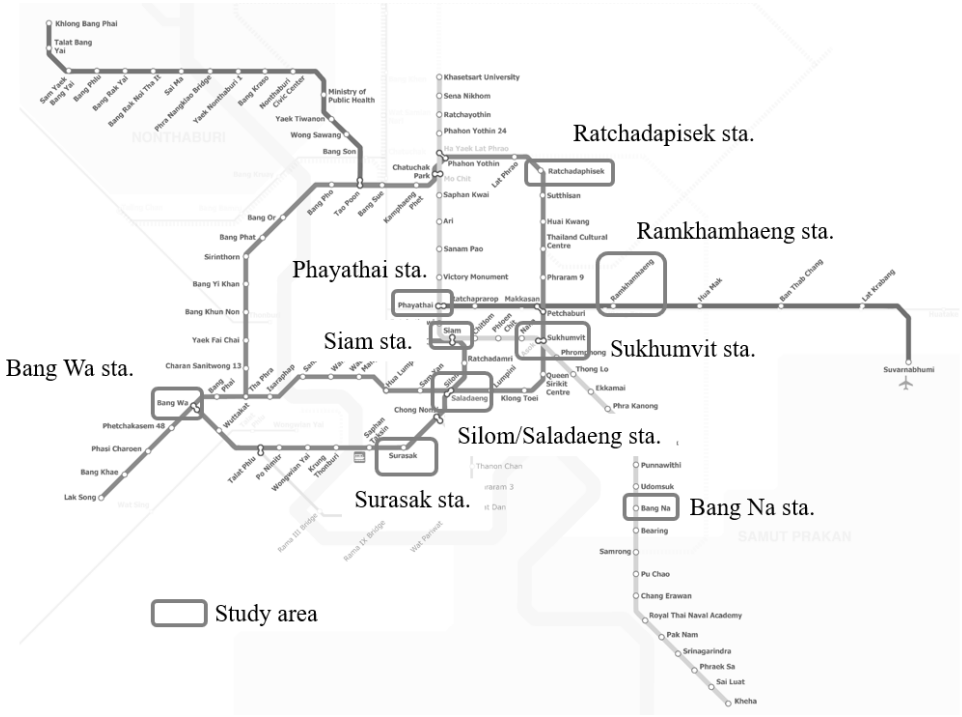


Figure 2. Observed stations

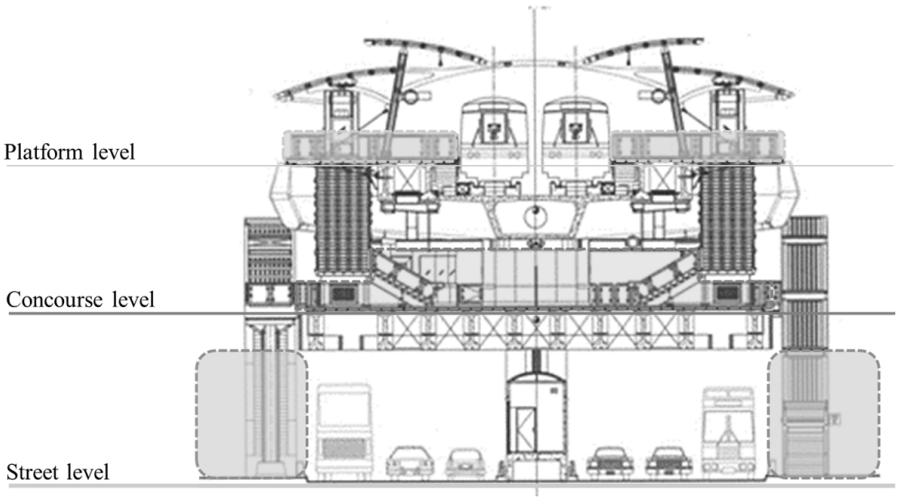


Figure 3. Typical components of a metro station, including street level, concourse level, and platform level (Source: Edited from (Bangkok Mass Transit System PLC Ltd. (BTS), n.d.))

6. Physical distancing measures at station

This study aims to investigate the length of physical distancing measures implementation at metro stations and in the passenger cars. Therefore, the data collection focuses on station areas and in the passenger cars where the COVID-19 mitigation takes place. Figure 3 illustrates examples of typical components in metro stations, including street level, concourse level and platform level. The data collection conducted via the measurement of actual length between physical distancing signages that installed by the metro operators for implementing a COVID-19 mitigation. The infection prevention measures are associated to the metro station facilities such as ticketing facilities, fare gates, security check points, elevators, staircases, etc.

6.1 Street level

The study found no physical distancing measures at the street level in all study areas.

6.2 Concourse level

The physical distancing mitigation at concourse level show 5 measures at ticket office, ticket vending machines, health check point, fare gate, and elevators line-up. Each metro operator applied a different style of physical distance markers. BTS stations used a "plus marker" in black, with 0.07 m x 0.07 m in order to keep passengers away from each other while using the concourse level as illustrated in Figure 4 (a). The MRT uses yellow line markers 0.22 meters long with a "stand here" message for indicating the exact position that passenger should be while lining up on the concourse level, as illustrated in Figure 4 (b). The ARL applied red line markers 0.3 meters long for indicating the distance between passengers at the concourse level as shown in Figure 4 (c).

This study compares the performance of physical distancing measures found at the concourse level in represented stations of each metro operator and the minimum physical distance encouraged by each operator's standard as shows in Table 2. The BTS applies 1.5 meter distancing between passengers while MRT and ARL apply the same length of 1 meter. The physical distancing at concourse level is between 0.9 meter at health check points in BTS stations and the longest distance of 1.47 meters, which also found in BTS stations. In comparison between actual physical distancing and operator's standard, BTS implemented all the measures lower than its standard with the lowest performance of -39.33% at health check points followed by -33.33% at the

(a) BTS station (b) MRT station (c) ARL station

Figure 4. Distancing markers at concourse level.

Table 2. physical distancing measures at concourse level

Metro operator	Physical distancing measures at concourse level									
	Ticket office		Ticket vending machines		Health check points		Fare gates		Elevators line-ups	
	d (m)	% from std.	d (m)	% from std.	d (m)	% from std.	d (m)	% from std.	d (m)	% from std.
BTS (std. = 1.5 meter)	1.47	-2%	1.11	-26%	0.91	-39.33%	1.00	-33.33	1.00	-33.33%
MRT (std. = 1 meter)	1.01	+1%	1.12	+12%	0.97	-3%	0.84	-16%	1.19	+19%
ARL (std. = 1 meter)	1.20	+20%	1.20	+20%	2.1	+110%	1.20	+20%	1.20	+20%

std. = standard of physical distancing
% from std. = percentage from rail operator physical distancing standard
d = distance between passenger (meter)

fare gate. MRT implemented physical distance at ticket offices, ticket vending machines, and elevator line-ups: a longer distance than its standard, but the distance between markers at health check points and fare gates were found to be shorter than 1 meter at -3% and -16% respectively. ARL applied all physical distancing measures longer than its standard, with the longest distance found at ARL stations: +110% at ARL station health check points.

6.3 Platform level

The results of survey show physical distancing at platform level of two features are metro platforms and waiting benches. The physical distancing markers used at platform level are illustrated in Figure 5. BTS stations used the “plus marker” the same as the markers use at concourse level but indicated in red and then changed to 0.145-meter-long yellow marker (the data as of 3rd May 2020) and apply white cross markers at waiting benches. MRT applies the same style of distancing marker as the concourse level, but the position of markers are in a zigzag form, and the waiting benches use a social distancing signs for preventing passengers from using in every other seat. ARL station platforms indicate the 0.145 meter-long white line to indicate the position of distancing measures to passengers waiting to board trains.

(a) BTS station (b) MRT station (c) ARL station

Figure 5. Physical distancing markers used at platform level.

Table 3. physical distancing measures at platform level

Metro operator	Physical distancing measures at platform level			
	Platform		Waiting bench	
	d (m)	% from std.	d (m)	% from std.
BTS (std. = 1.5 meter)	1.10	-26.67%	0.54	-64%
MRT (std. = 1 meter)	1.11	+11.00%	0.51	-49%
ARL (std. = 1 meter)	1.20	+20%	0.6	-40%

std. = standard of physical distancing
% from std. = percentage from rail operator physical distancing standard
d = distance between passenger (meter)

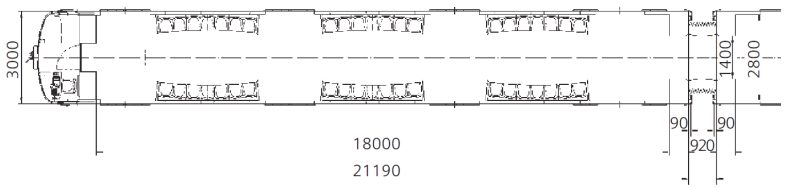


Figure 6. The components of metro passenger car (Source: Siemens AG)

Table 3. displays the physical distancing measures at platform level including platform and waiting bench facilities. The physical distances applied at the platform are between 1.1 to 1.2 meters, and at the waiting benches, 0.54 to 0.6 which is considered 40% to 64% lower than each operator's standard. ARL implemented the longest physical distance at the platform in terms of platforms and waiting benches.

7. Physical distancing measures in passenger cars

General metro passenger cars in Bangkok illustrated in Figure 6. The arrangement inside the metro passenger car was designed for high capacity which minimized seat space and encouraged a high portion of hallway due to the high-density urban area operation.

The COVID-19 mitigations in passenger cars implemented by metro operators in Bangkok organized the space inside the train by installing markers on seats and floors as displayed in Figure 7 for preventing use of every other seat using markers to let passengers avoid using those subject seats and keep social distancing between passengers. The marker illustrated in BTS train has 0.25 m x 0.18 m red signage with the message "do not sit" in Thai and English on the backrest. MRT train applied a 0.21 m x 0.21 m cross yellow marker at the backrest of passenger seat and 0.22 meter-long yellow line with a "stand here" message on the floor. ARL installed 0.23 m x 0.23 m cross markers with a red-white striped rectangular warning and a 0.20 meter-long check marker in a red-white striped rectangular warning on the floor.

(a) BTS (b) MRT (c) ARL

Figure 7. Physical distancing markers used in passenger car.

The length between markers in passenger car are shown in Table 4. Passenger distancing is shorter than at both concourse and platform level. The seats in BTS and MRT train apply significantly shorter physical distance than its standard: it was -68.66% for BTS and -57% for MRT. There is no standing marker in BTS trains and in MRT found to be 0.6 meter which is -40% from its standard. Only ARL seats and standing areas installed the markers regarded as its standard at 1.05 meter.

Table 4. dimension of physical distancing signs in passenger cars

Metro operator	Dimension of physical distancing signs in passenger car			
	Seat		Standing area	
	d (m)	% from std.	d (m)	% from std.
BTS (std. = 1.5 meter)	0.47	-68.66%	-	-
MRT (std. = 1 meter)	0.43	-57.00%	0.60	-40%
ARL (std. = 1 meter)	1.05	+5%	1.02	+2%

std. = standard of physical distancing
% from std. = percentage from rail operator physical distancing standard
d = distance between passenger (meter)

8. Results

The passenger level of infection risk from close contact transmission by breathing during the time at the metro station is interpreted in Figure 8. The physical distancing measures are interpreted as the average distance between passengers according to the location that activities take place in the metro station: concourse level, platform level, and in the passenger car during commute.

The average physical distance at the concourse level shows that all metro operators organized the physical distance that is safe enough if passengers are required to wear at least cotton masks which protect from airborne transmissions at 1.05 meter between the passengers. The average physical distance at platform level is considered from the distance between standing markers for lining up in order to board the train and the physical distancing marker at the waiting seat on the platform. BTS and MRT organized the

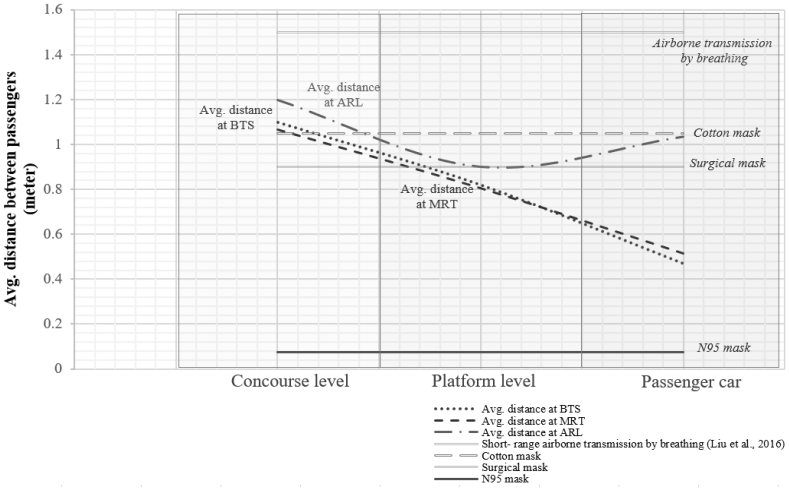


Figure 8. Average distance between passengers at metro station and in passenger car compared with protective mask efficiency

average physical distancing as 0.82 meters and 0.805 meters respectively, which are unsafe for passengers wearing cotton masks and surgical masks. In a case when all the positions are occupied at the platform level, all the metro operators had risk from the passenger who used the waiting seat at the platform and did not wear a N95 mask due to the physical distancing measures at the waiting seat applied from 0.51 meter to 0.6 meter, which is shorter than the minimum distance required for airborne transmission between passengers who wear surgical masks, of 1.05 meter.

The average physical distances in passenger car are 0.47 meter, 0.515 meter, and 1.035 meter for BTS, MRT, and ARL. This shows unsafe conditions for BTS and MRT passengers who are not wearing N95 masks during the metro commute in fully occupied space regarding physical distancing measures. In contrast, the average distance between passengers in ARL trains presented a safe condition for passenger wearing a surgical mask and the distance is closest to minimum requirements of wearing cotton masks for preventing the COVID-19 infection through short-range airborne transmission.

9. Conclusions

Metro operation responses during COVID-19 pandemic concentrate on the physical distancing measures to prevent infection from droplets and aerosol transmission which are caused by close contact between passengers at metro stations and during train journeys. The physical distancing measures in metro operations are found at meso level mitigations as the train operators have announced and implemented physical distancing designed to keep passengers away from each other. This mitigation stimulates avoiding close contact between passengers and also station staffs throughout the metro system and station to encourage the safety protocols during the pandemic. As a result, the implementation of physical distancing measures of all metro operators are the most strict at the concourse level. The surveyed physical distance at concourse level reports satisfactory suitable physical distancing regarding the metro operator standards. The BTS standard is set at 1.5 meter which is highest among metro operators in Bangkok, but the actual physical distancing measures are similar to MRT and ARL. As a consequence, BTS physical distancing measures performance at concourse level presents a discrepancy between company mitigation and actual physical distancing displayed at the station. For the platform level, the physical distancing measures at standing areas satisfy the safety standards, but when considered with the physical distance markers at waiting seats, the average distance reported a higher level of infection risk due to the several materials of protective masks that passengers use during the time at metro stations and also during journeys. The recommendation given for this level is to prevent use of waiting seats to reduce the risks at the platform area. In passenger cars, there is an enormous discrepancy between infection safety standard and actual physical distancing implemented in BTS and MRT trains. This area contains the highest risk of COVID-19 infection in metro trips. Especially when all the available spaces are taken, the physical distancing inside the train will not be far enough for minimum physical distancing requirements for surgical masks. Moreover, there is no standing marker in BTS passenger car which potentially lead to a uncontrollable of physical distancing during the travel trip. In other words, passengers are required to wear an N95 mask to be safe during using BTS and MRT metro services. Only ARL provides physical distancing that exceeds the infection safety standard and minimum physical distancing requirement of using a surgical mask and is close to minimum requirements of using cotton masks to protect from COVID-19 infections.

We discuss that the findings of this study can only identified the risk of coronavirus transmission at the low to medium ridership due to lock down policy and observed in full capacity under the implementation of physical distancing measures. Therefore, If the situation is getting more relaxed and the metro operators allow passengers to enter its system at general metro capacity, the level of infection risk would be different to the results mentioned in this study.

10. Acknowledgements

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