Effects of Exit Discharge Congestion on the Effective Evacuation Time in a Typical Underground Metro Station Design

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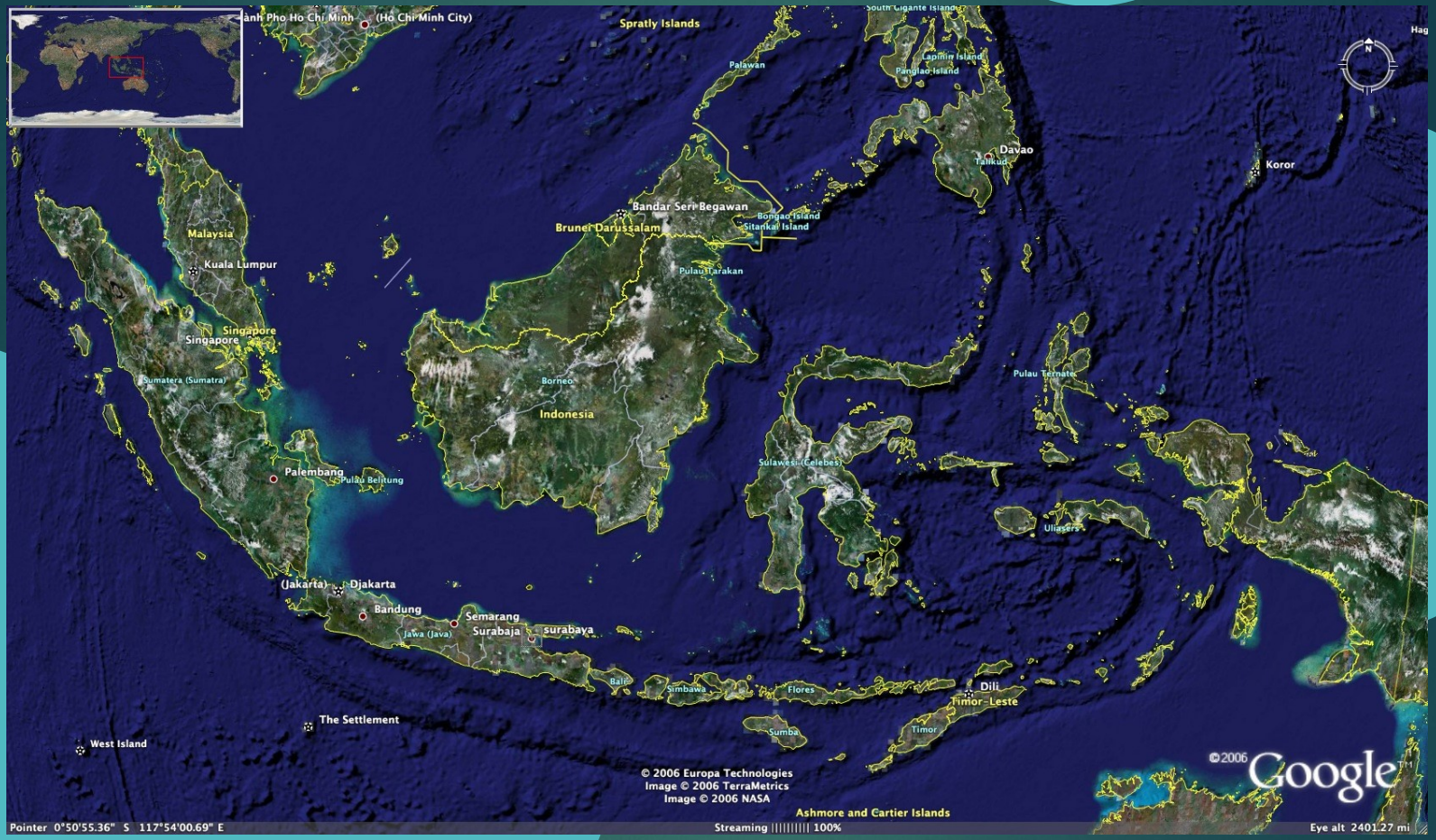
Outline of Talk

- Introduction and background
- Underground Metro system
- Fire safety concerns in Underground Metro System
- Safe evacuation criteria
- Effects of the crowds near entrances/exits discharge on the effective evacuation times
- Conclusions

Map of Indonesia



Sabang in Aceh

Merauke in Papua

More than 5 hour flight

Indonesia on the map of the World

http://geology.com/world/world-map.shtml

Universitas Indonesia

- 50.000 students
- 6.000 faculty members
  (full and part time faculty)
- 800 acres of greenary space
- 13 Schools/Faculties

Veritas – Probitas – Iustitia
founded since 1849
(Doktersdjawa School)
bearing the name of
Universitas Indonesia since 1950

Fire Safety Engineering at UI

- Department of Mechanical Engineering, Universitas Indonesia offers an elective module in Fire Safety Engineering and research topics in fire safety for BEng., MSc., and PhD levels.
- Research objectives: Development of Innovative Fire Safety Methods and Technologies for Supporting the Appropriate Implementation of Performance-based Design Approach

Background : Jakarta Traffic Congestion

1. The loss of productive time and working hours
2. Waste of energy (fuel) due to increase of vehicle operating costs
3. Increase individual and society stress.
4. Loss of family time

Choices of Mass Transportation Modes

- Bus Rapid Transit (BRT) – Busway
- Light Rail Transit (LRT) – Monorail
- Mass Rapid Transit (MRT) – Elevated + Underground System tracks
- Waterways

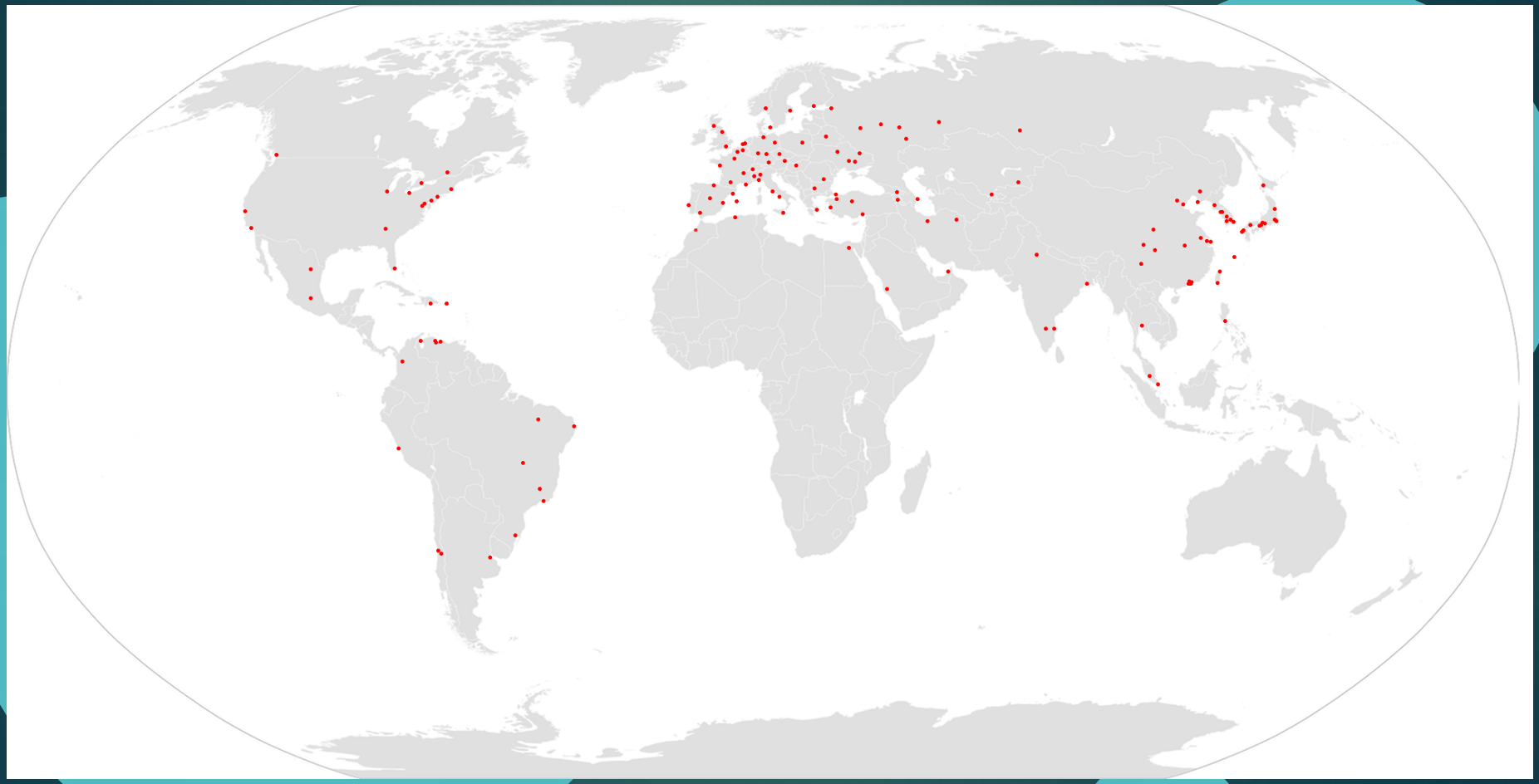
MRT / Metro Underground Tunnel

- A metro system is a rapid transit train system.
- In some cases, metro systems are referred to as subways or undergrounds.
- As of May 2013, there are 188 metro systems in 53 countries in the world.
- The first metro system, the London Underground, was opened in 1863.
- The New York City Subway has the most stations and the longest amount of total track, with a total of 842 miles (1,355 km).

Why MRT / Metro System ?

- High capacity and high frequency of service,
- Clean (as it is an electric passenger transport system)
- Totally independent from other traffic, road or pedestrians.
- Most metro systems do not share tracks with freight trains or inter-city rail services
- Lowering cost of transportation in many big cities of the World

Cities of the World with Metro System



Ref. wikipedia.org

Fire Safety Concerns in Underground Metro System

Moscow Metro fire, June 5, 2013

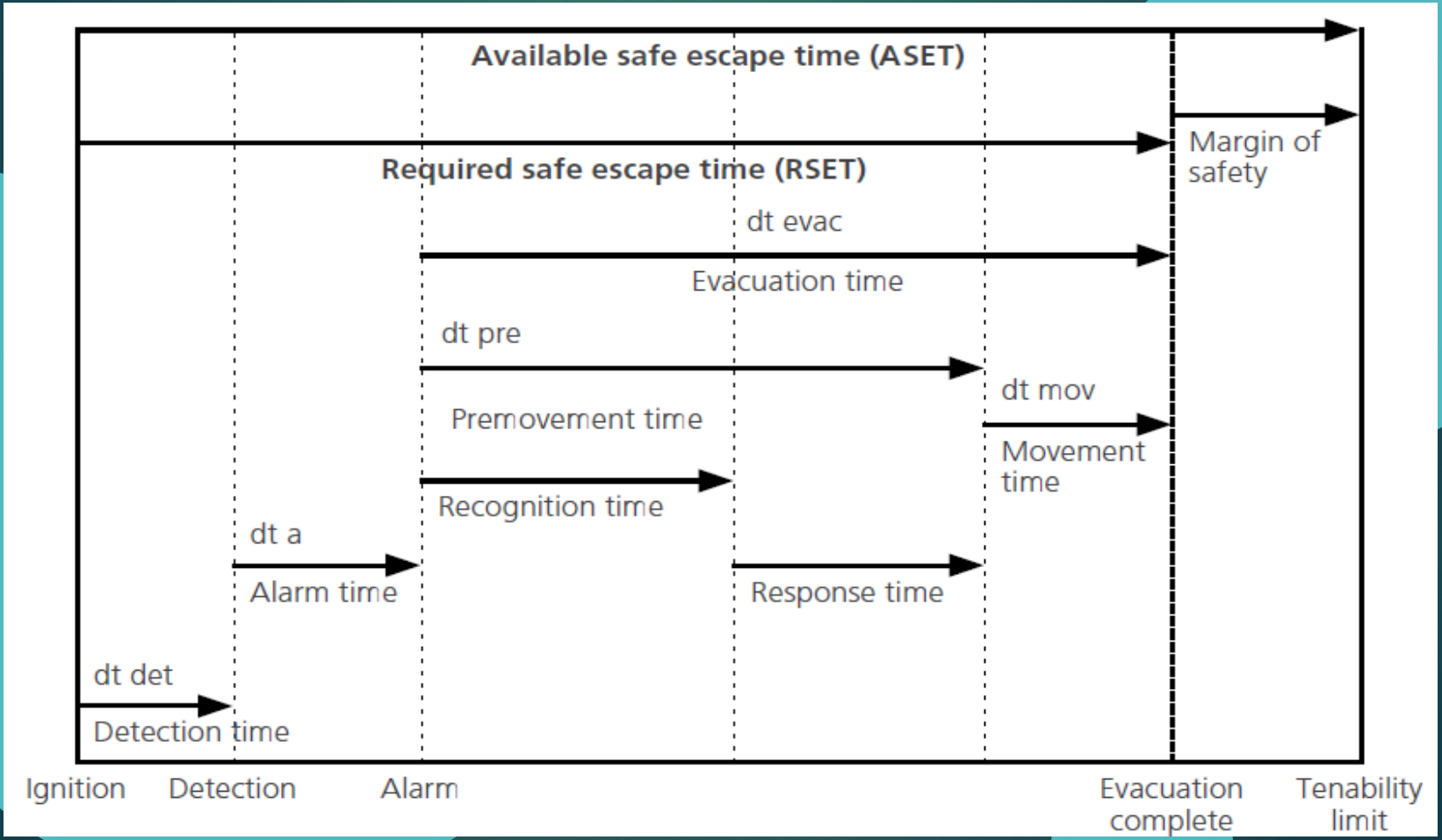
http://rt.com/news/metro-moscow-evacuation-fire-243/

Means of Escape

Means of escape are structural and integral part of the construction which allow people to proceed to a place of safety in the event of a fire.

Means of escape includes exit doors, corridors and staircase which lead to the open air or exit discharges.

Safe Occupant Requirements



Bottom line

To provide a tenable environment within the scope of operation, long enough for operators/ occupants to leave the space safely.

$$ASET > RSET$$

Evacuation Modeling

Several evacuation models are now available and widely used.

Exodus simulation characteristics

Uses C++ and rule based agents.
Tracks every individual
5 sub modules employed – Occupant, Movement, Behavior, Toxicity, and Hazard

Pathfinder Characteristics

Agent based simulator that uses steering behaviors
3 modules – Pre-processor writes files for the Simulator, and the Post-Processor reads files from the Simulator module
Agent mode uses AI; FPE mode uses scripts from Report Engineering Guide.

FDS+EVA Characteristics

Uses and equation of motion that totals a force from the surroundings, agent properties, and escape strategy to choose where the agents go

Evacuations of Underground Metro Station

Problems in designing underground metro station with evacuation in mind:

- Station building is large and connected to other premises.
- The distances to evacuations can be long.
- The population is numerous and complex, although mostly familiar with the building.
- Many places where bottlenecks may occur, such as stair areas and ticket gates.

Safe Evacuation Criteria

According to the NFPA 130 (2010) it is required that the egress capacity of the platform should guarantee to evacuate the platform occupant load in 4 min or less and 6 min for the completion of evacuation.

Meanwhile, according to Japanese code (MLIT, 2012), the smoke density during evacuation ≤ permissible smoke density (**Cs = 0.1 (1/m**). This is equivalent to the visible distance required for an unspecified number of people to evacuate (15 to 20 m).

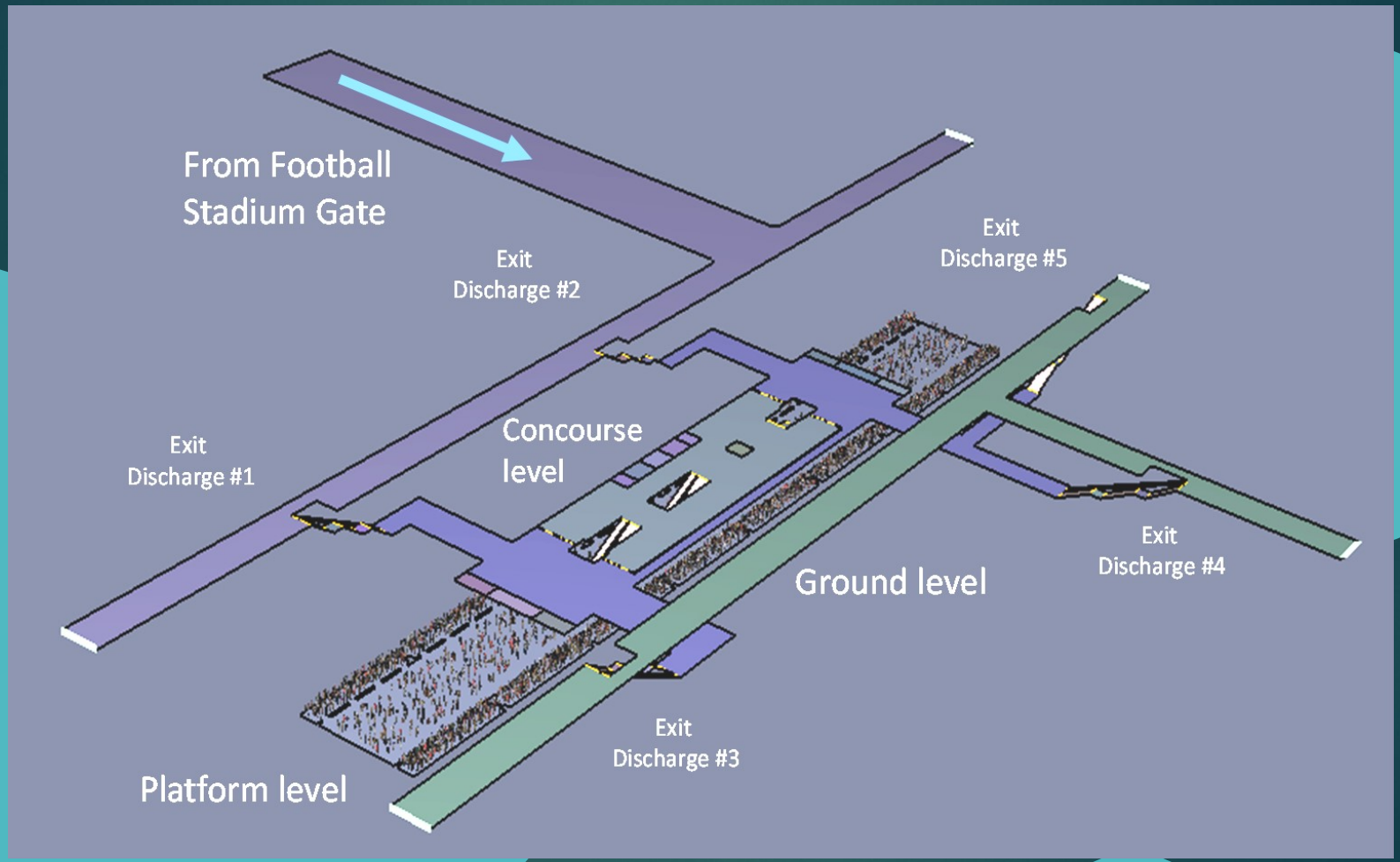
Similar to those of the performance based design, the Japanese code requires several checking procedures to verify evacuation safety for all underground stations in which their characteristics are depend upon the station types, location of fires, type of fires (ordinary or arson fires).

Overview of the Metro Station Design Studied

The metro station represented in the present simulation work is a two-storeyed **underground island station**, located near the Jakarta main stadium. This station is typically has 220 m long and 21 m wide. The metro station's first underground floor is the concourse floor, and the second underground floor is the platform floor, which has an effective platform length of 170 m enabling of 8 cars for future use.

There are two escalators three stairs from the platform to concourse, and four exit passages on the concourse floor leads to five exits on the ground level. In addition, there are two firefighter shafts and a vertical lift. The firefighter shafts and the vertical lift are not included for use in the emergency evacuation. The automatic gates in the concourse floor include two groups of exit automatic gates and the side doors. In case of fire, all the entrance/exit gates and side doors should be opened for evacuation.

3D Station Design



The side walk width on the ground level is 650 cm.

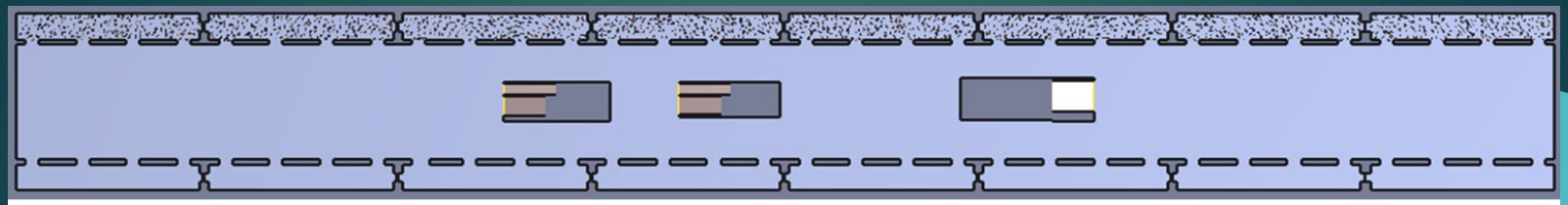
Occupant Characteristics and Distribution

The station studied is located in the main business road, hence it is assumed that the typical occupant characteristics and distributions are as follows:

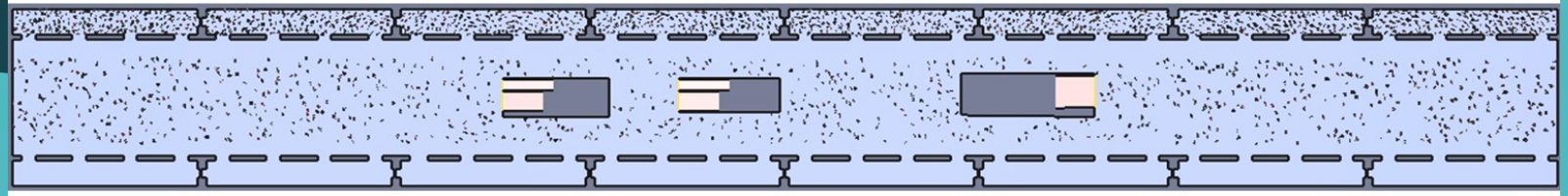
Table 1: Occupant characteristics and distribution.

	Percentage (%)	Walking speed (m/s)	Shoulder width (cm)
Male	43.9	1.1	46
Female	38.1	1.0	43
Elderly	8.9	0.9	44
Child	9.1	0.85	37
Crowds			
10 to 30 persons standing near the exits.		0.0	46

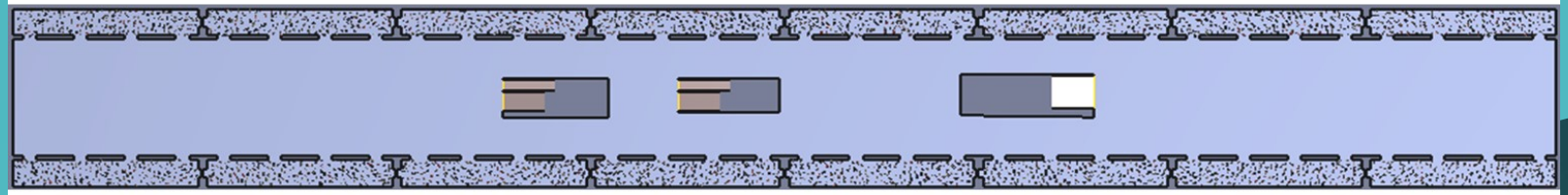
Number of Passenger for Evacuation Studies



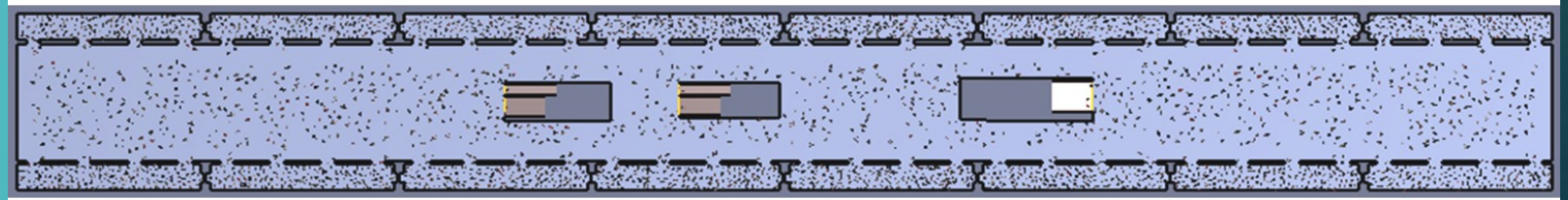
100% car capacity : 1254 persons



175% car capacity : 2195 persons

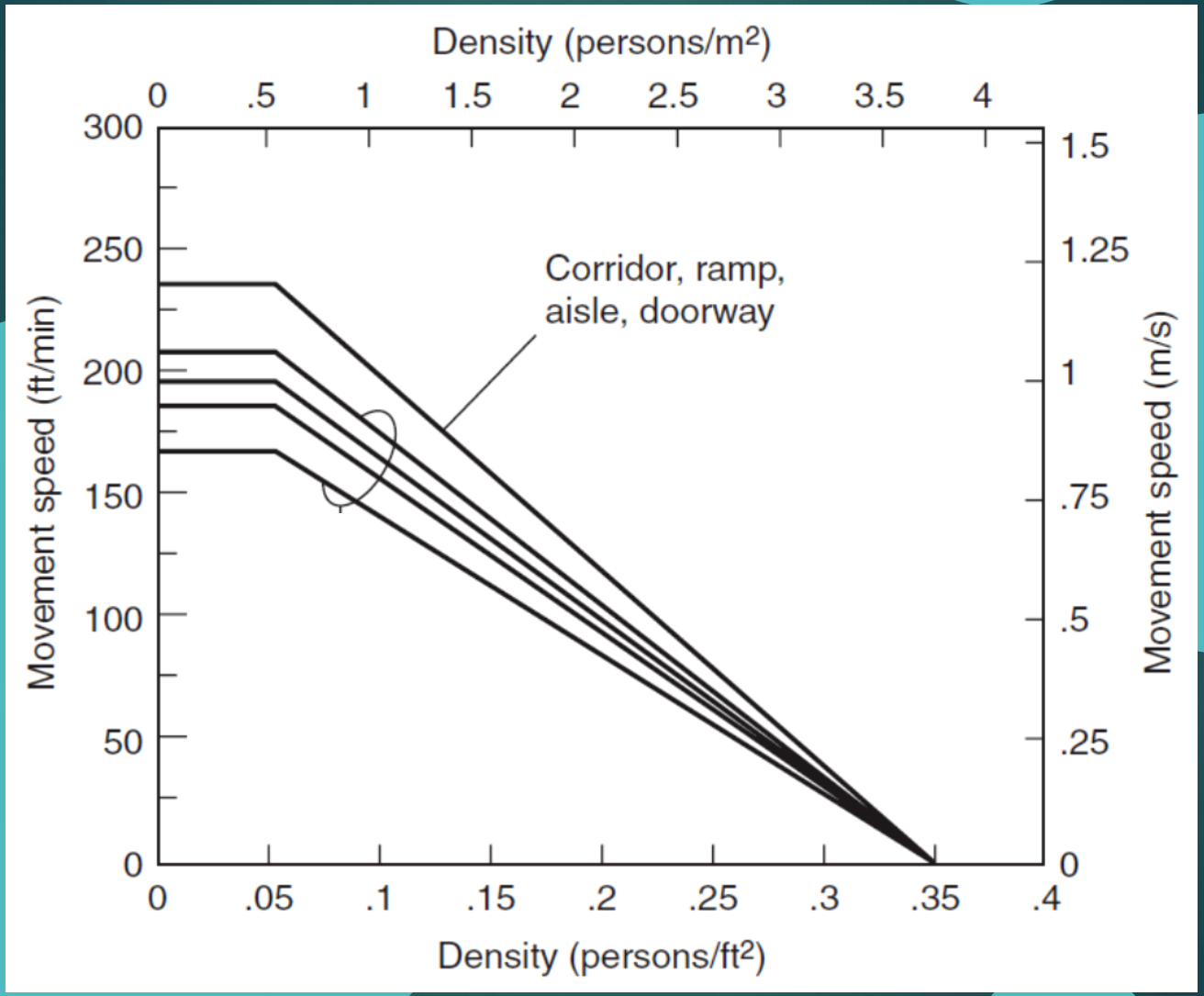


200% car capacity : 2506 persons



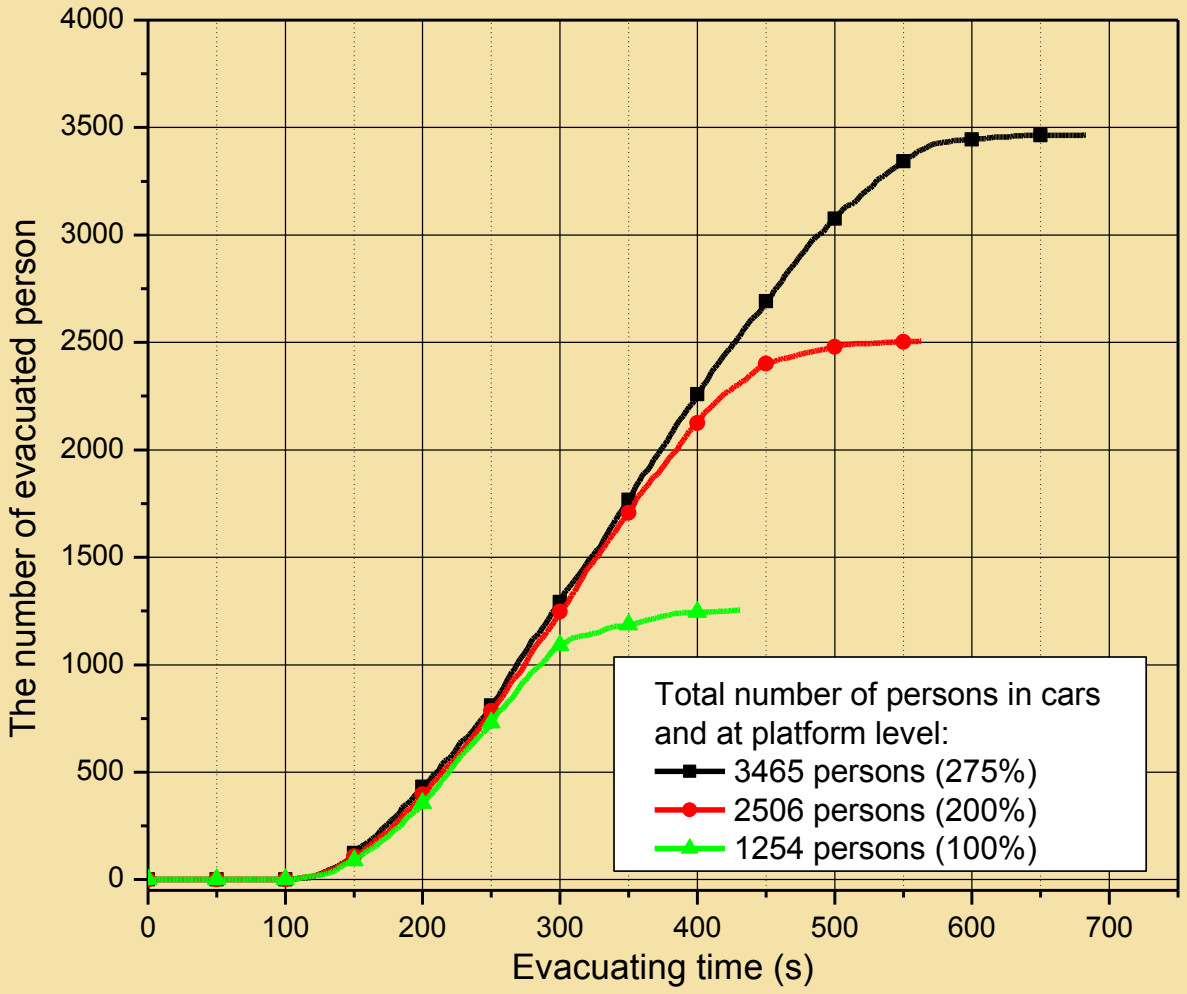
275% car capacity : 3465 persons

Effect of Crowd Density



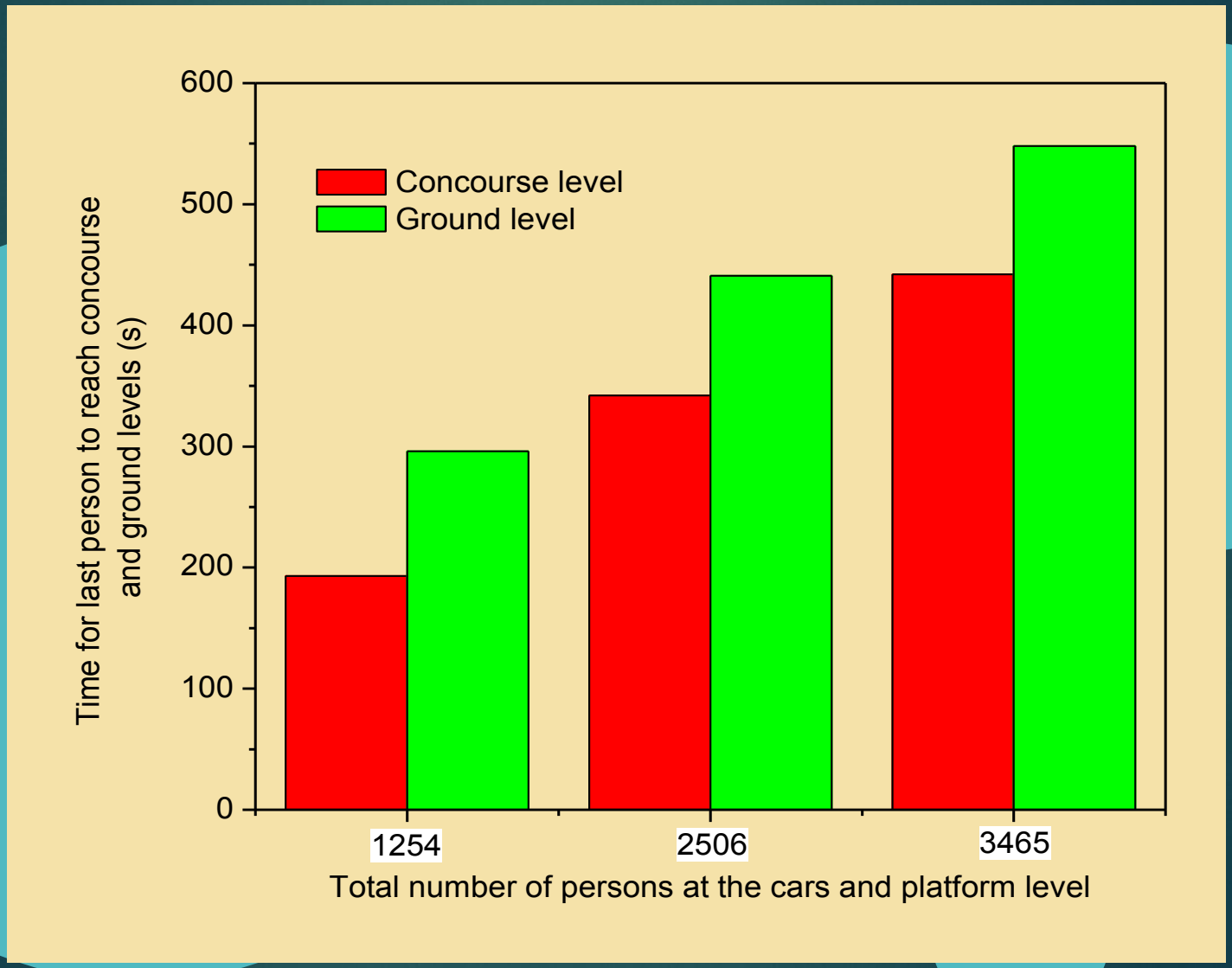
Evacuation speed as a function of density (Nelson, H.E., and Mourer, F.W., 2002)

Results of Varying Number of Passengers during Evacuation

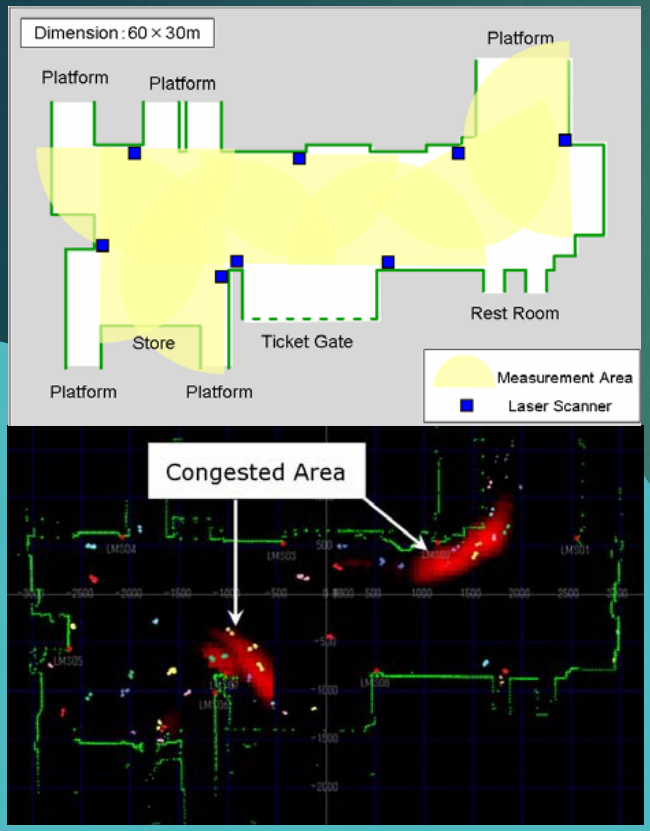


Comparison of the dynamic curves of the persons evacuated from the train cars and from the platform floor to the concourse level and to the ground floor, in the case of fire on the platform.

Results of Varying Number of Passengers during Evacuation (Cont)



Development of Crowds in a typical Underground Metro Station

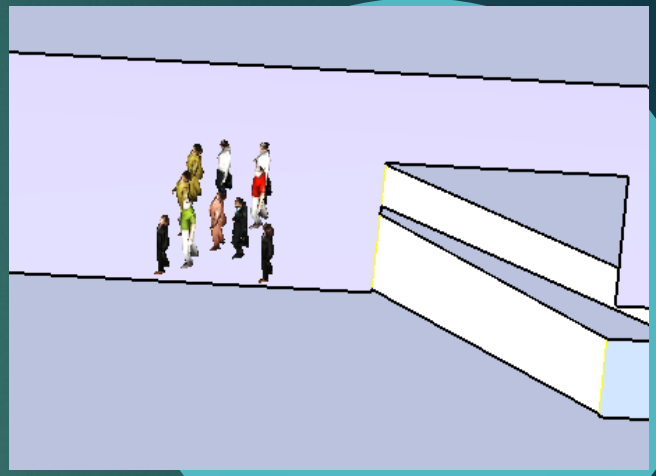


Fire emergency condition [Moscow Metro Fire, 2013, source: rt.com]

Normal situation [K. Katabira, et al., 2008]

Understanding people behavior or flows becomes increasingly important for several reasons, e.g., floor planning, alignment of advertising messages, and mitigation of congestion during normal and emergency conditions, etc.

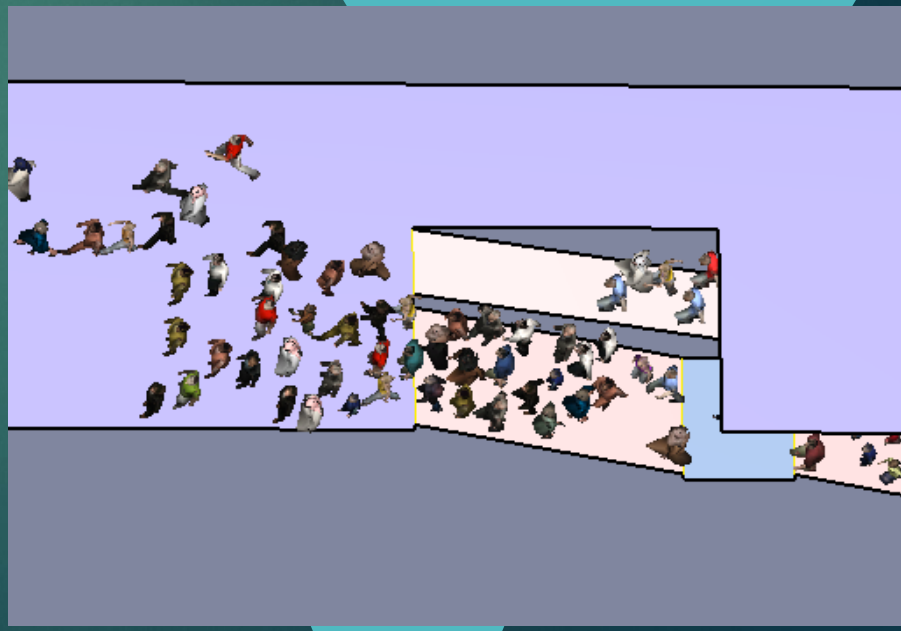
Effects of the Crowds near Entrances/Exits Discharge



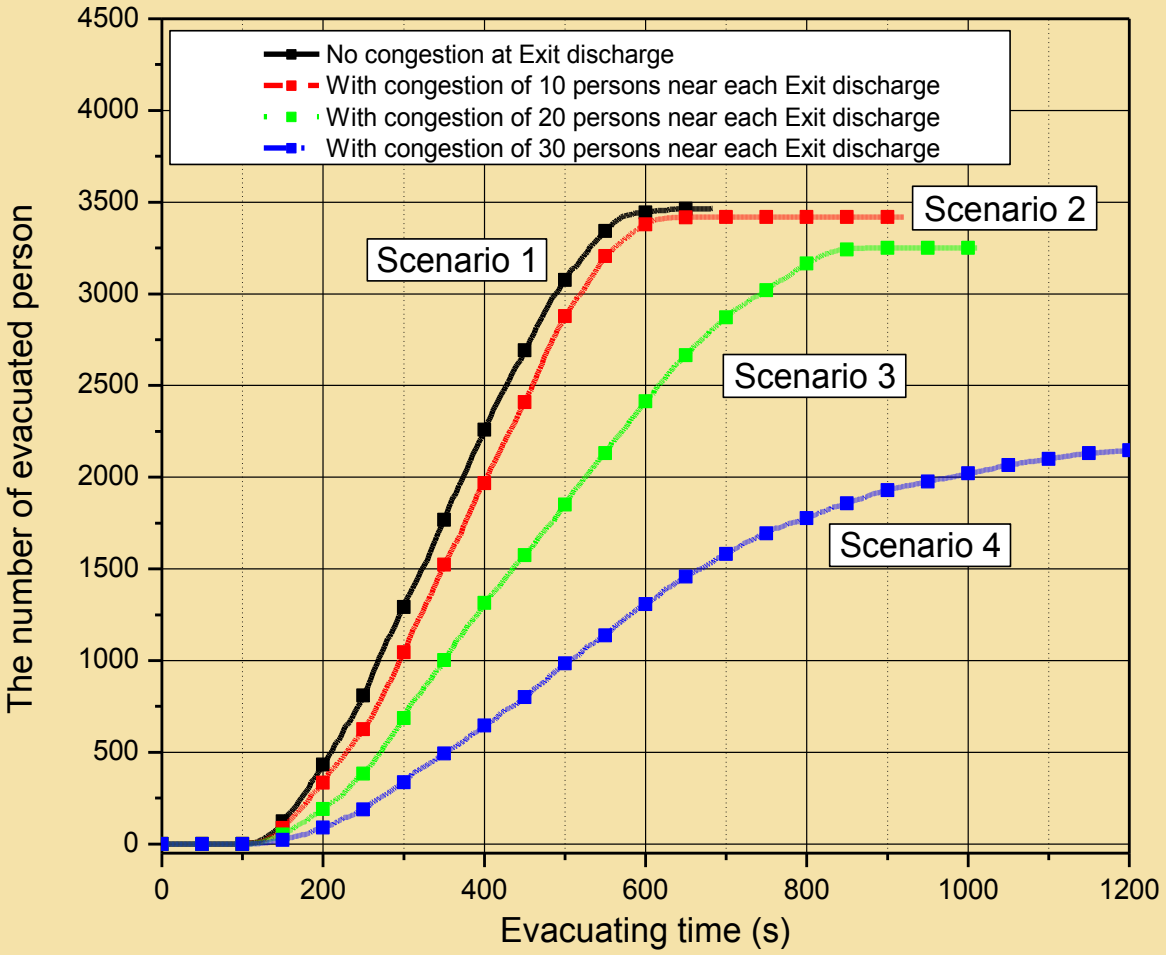
To study the effects of the crowds on the congestions developed near the station entrances/exits discharge, four crowd scenarios have been considered as follows:

- Scenario 1: No crowd situation
- Scenario 2: Crowd of 10 persons standing on the area of 10 m2, 2 m from the exit discharge point.
- Scenario 3: Crowd of 20 persons standing on the area of 10 m2, 2 m from the exit discharge point.
- Scenario 4: Crowd of 30 persons standing on the area of 10 m2, 2 m from the exit discharge point.

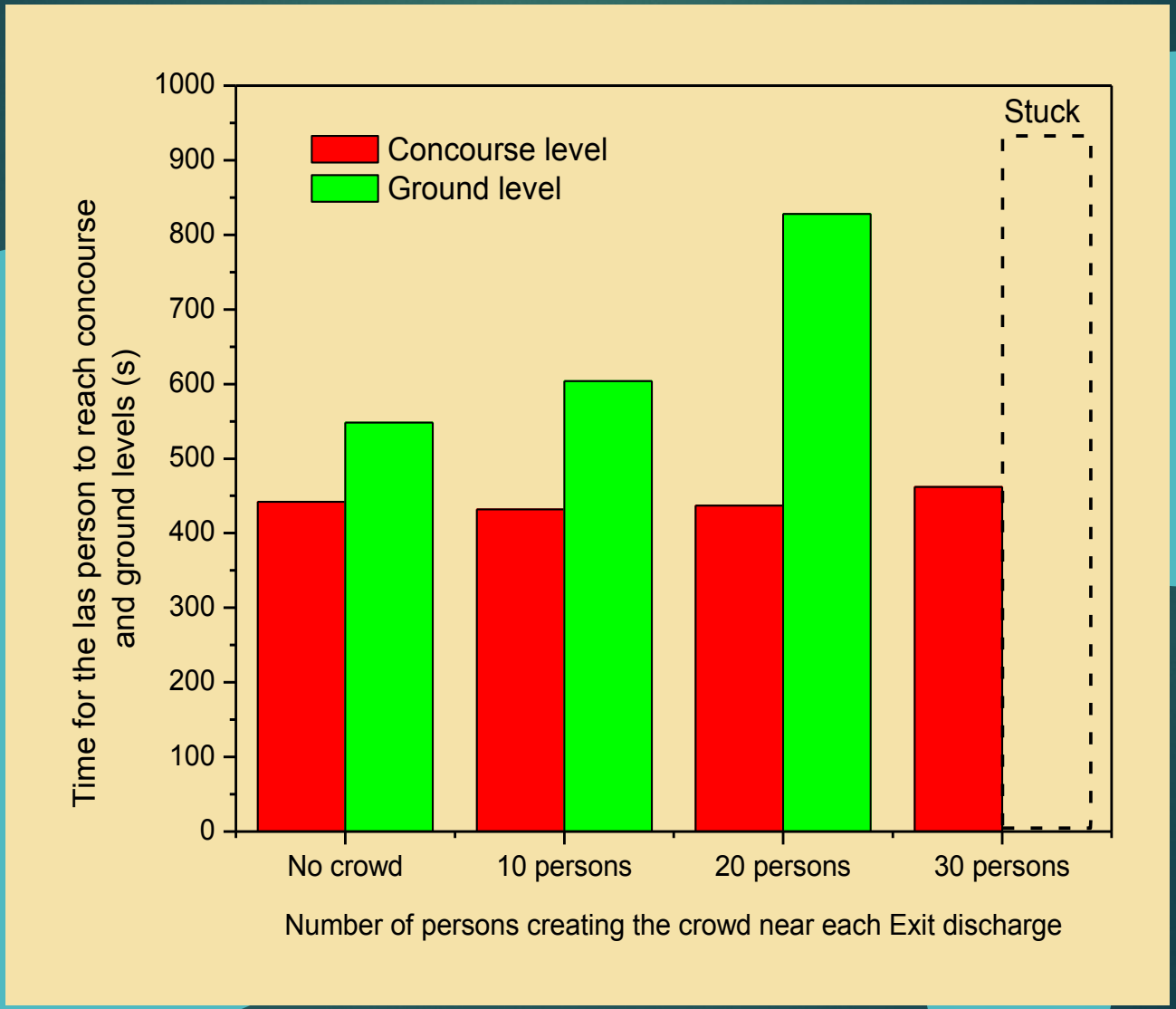
Congestion Locations



Effects of the Crowds near Entrances/Exits Discharge



Effects of the Crowds near Entrances/Exits Discharge



Conclusions

Modeling of the evacuation processes of a typical island type underground metro station has been carried out for different number of persons involved and various congestion scenarios at the exit discharge area.

Although the evacuation time for evacuates on the platform floor to the point of safety at the concourse level are not affected by congestion at the exit discharge, the results suggested that a great attention should also be put on securing the smooth movement of the evacuates to the so called assembly area close to the exit discharge.

A secured area on the ground floor should be designated for this purpose.

Acknowledgement

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