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Preliminary View on Fire Safety for Rapid Passenger Rail System in China

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Topics Covered

1. Introduction
2. Meaning of High Speed Train
3. Fire Characteristics
4. Research in China
5. Research Plan Proposed by the Principal Author
6. Conclusion

1. Introduction

- ★ **The total length of the railway lines in China is 75438 km. (2005 statistics by the Ministry of Railways)**
- ★ **High speed trains are under active development in the Mainland.**
- ★ **Covering 17 provinces.**
- ★ **Including the Jing-Ha (京哈), Jing-Guang (京广), Zhe-Gan (浙赣), Hu-Hang (沪杭), Jing-Hu (京沪), Long-Hai (陇海) and Jiao-Ji (胶济) lines.**

- ★ **After 5 improvements in speed, the fastest train in China can travel at 160km/h.**
- ★ **After the upgrading, the fastest passenger train can travel at above 200 km/h; certain zones of the Jing-Ha, Jing-Hu, Jing-Guang and Jiao-Ji lines can be up to 250 km/h.**
- ★ **The 6th upgrade in train speed will be carried out on 18 April 2007.**

Mid and Long-term Plan for Railway Network and the 11th '5 year' Plan for Railway Network by the Ministry of Railways:

- ★ **Speed is designed to be 300 to 350 km/h.**
- ★ **4 vertical passenger lines: Jing-Hu (京沪), Jing-Guang-Shen (京广深), Jing-Ha (京哈) including Shenda (沈大) and Hang-Ning-Fu-Shen (杭宁福深); and 4 horizontal passenger lines: Chu-Lan (徐兰), Hang-Nan-Chang (杭南长), Qing-Shi-Tai (青石太) and Ning-Han-Yu-Rong (宁汉渝蓉).**
- ★ **It is estimated that in 2010, the total length of the newly built high speed railway lines with speed above 200 km/h will be 9800 km, about 49% of the total railway length.**
- ★ **More and more high speed trains will be put in operation alongside the development of the rapid rail system.**

Mid and long-term plan for railway network in China (Chinese Government Website)

- **Beijing-Shanghai : high speed railway with a total length of 1320 km is designed to have a maximum speed of 350 km/h and traveling speed of 300 km/h; expected to be in operation in 2010.**
- **Shanghai-Hanzhou line operated.**

(Yazhou Zhoukan, 18 February 2007)

- ★ **Serious problems might come from high speed train fires:**
  - **fast speed**
  - **small and enclosed space**
  - **high passenger loading**
- ★ **Though not many tragic fire incidents had happened since high speed trains were put into service in the past decades, fire safety for high speed trains should be studied.**

- ★ **Shanghai maglev train has a total length of 30 km, running from the south of Shanghai Subway Line 2 Longyang Street Station (龙阳路) to east of the terminal building of Pudong International Airport Phase 1.**

December 2006

(http://news.xinhuanet.com)

2. Meaning of High Speed Train

- ★ **Speed over 200 km/hr.**
- ★ **More and more appear all over the world.**

TVG – French high speed train (300 km/h)

Shinkansen 300 - Japanese high speed train (275 km/h)

(http://www.travel-e.net/le-Train/Train-Eurail-Other.htm)

- ★ **High speed trains is identified as one of the major transport means in the 21th Century in China.**
- ★ **There were not many studies on high speed trains in China compared with other countries.**
- ★ **Not many rapid railway lines have been built in China at the moment.**
- ★ **After the 6th upgrade in speed for railway trains, the maximum speed for the passenger train can reach above 200 km/h.**
- ★ **Certain zones of the Jing-Ha (京哈), Jing-Hu (京沪), Jing-Guang (京广) and Jiao-Ji (胶济) lines can be up to 250 km/h.**

- ★ **After joining the World Trade Organization, significant progress in the research on high speed trains has been made in China.**
- ★ **“China Star”- a high speed passenger train designed in China, running from Qingwangdu (秦皇岛) to Shengyang (沈阳).**
- ★ **The maximum speed of “China Star” is up to 321 km/h.**

(http://baike.baidu.com/pic/49/11581283744146732.jpg)

China Star (中华之星), up to 321 km/h

High Speed Trains in China

(http://bbs.tiexue.net/post_1615838_1.html)

Type	Maximum speed km/h
DJJ1 (Nanjian 南箭)	305 (Expt)
Shaoshan Type 8 (韶山 8 型)	240 (Expt)
DDJ1	240 (Expt)
Changbaishan (长白山)	190 (Expt)
DJJ2 (China Star 中华之星)	321 (Expt)
XYZ (Pioneer 先锋号)	200 (Expt)

Changbaishan (长白山号)
250km/h

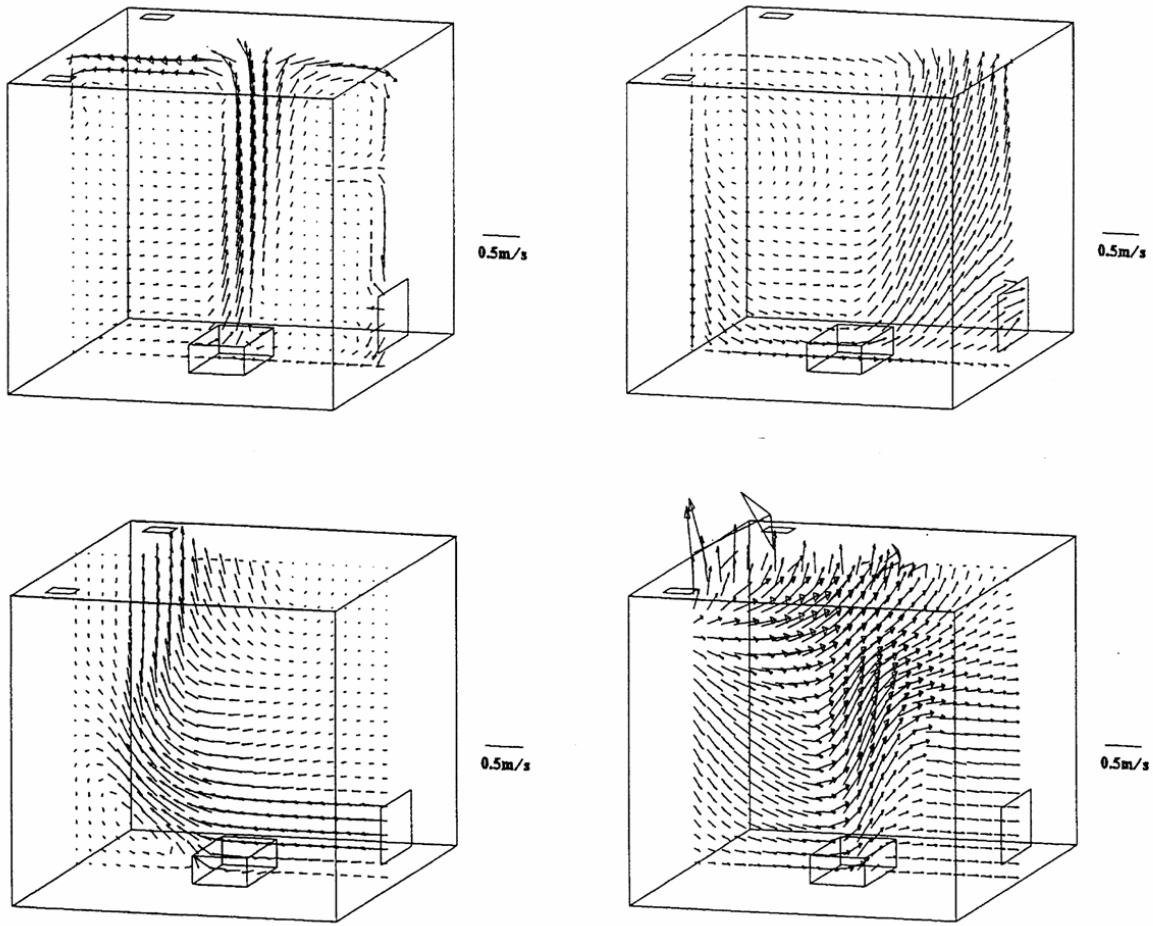
Star of Central Plains (中原之星)
548 persons,160 km/hr

High speed train running on Guang-Shen line, maximum speed 200 km/hr

3. Fire Characteristics

Operating characteristics

- ★ **High fire load carried**
- ★ **High passenger loading : evacuation problems**
- ★ **Small vehicle : ease to have flashover**
- ★ **High speed : acoustic design, enclosed**
- ★ **Ignition sources**
- ★ **Ventilation : mechanical locations of air intake and exhaust**



Up: In
Down: Out

Fire Field Model
Forced-ventilation chamber

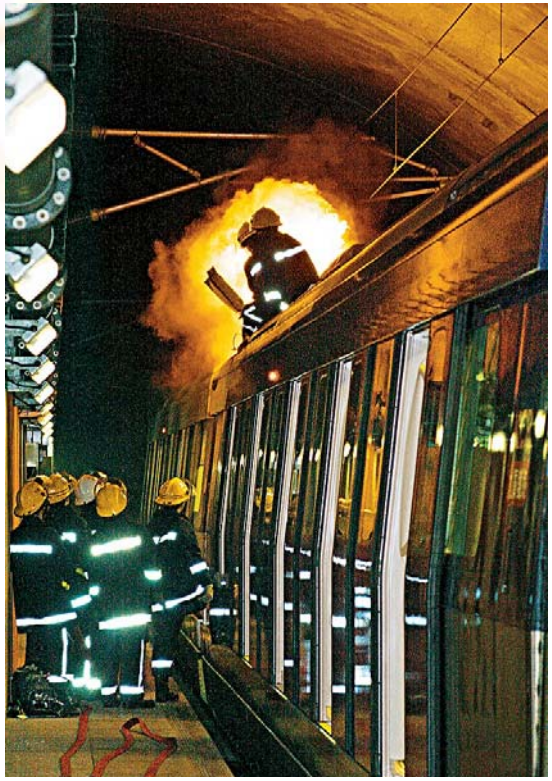
Well managed like air plane in new operation !
Very different arrangement afterward !

- ★ **Fire risks:**
- ★ **High fire load density**
- ★ **Hidden problems such as ignition from transformer**
  (Over 2 fires in Hong Kong, just one in February, 2007)
- ★ **Fire spread over materials**
- ★ **Difficulties in fire-fighting**

Railway stations affected by the heavy snowfall

Consequent to Zhengzhou Snowfall January 2006

- ★ **Life safety**
- ★ **Property loss**
- ★ **Suspension after fire would give economic loss**



KCR West Rail fire on 14 February 2007
(Apple Daily, 15 February 2007)

4. Research in China

- ★ **Research on train fires in China is just starting.**
- ★ **Nothing has been done on high speed trains.**
- ★ **Guides and technical standards such as《铁路消防管理办法》,《旅客列车消防安全管理规定》,《铁路工程设计防火规范》just issued in China for ordinary trains.**

In contrast :

- ★ **Many studies had been carried out on the causes of fire incidents, firefighting techniques and evacuation in ordinary trains and tunnels by the railway authorities in some countries.**
- ★ **USA, Korea Australia, UK, Japan, …**
- ★ **Mathematical models, materials with small-scale, medium-scale and large-scale experiments.**

Mainland Works (Named a few!)

- ★ **Experimental studies on the smoke characteristics and temperature profile for a ordinary train compartment fire by Du et al. at the China University of Mining and Technology.**
- ★ **Characteristics of smoke layer height for a train fire inside a tunnel by Zhou et al. using the software Fire Dynamics Simulator.**
- ★ **Simulations on the evacuation of passengers in a maglev train using Computational Fluid Dynamics by Li et al.**
- ★ **Consultancy on performance-based design of subway stations.**

Most works published in Chinese, very few in overseas SCI journals yet!

Research by the Principal Author

★ **Subway system in Hong Kong**

Station: Assisting government in approving and consultancy for performance-based design (Hong Kong, Taiwan, China)

Tunnel: Smoke Management System

Ventilation System

(Several PhD and MSc projects)

Train: Heat Release Rate

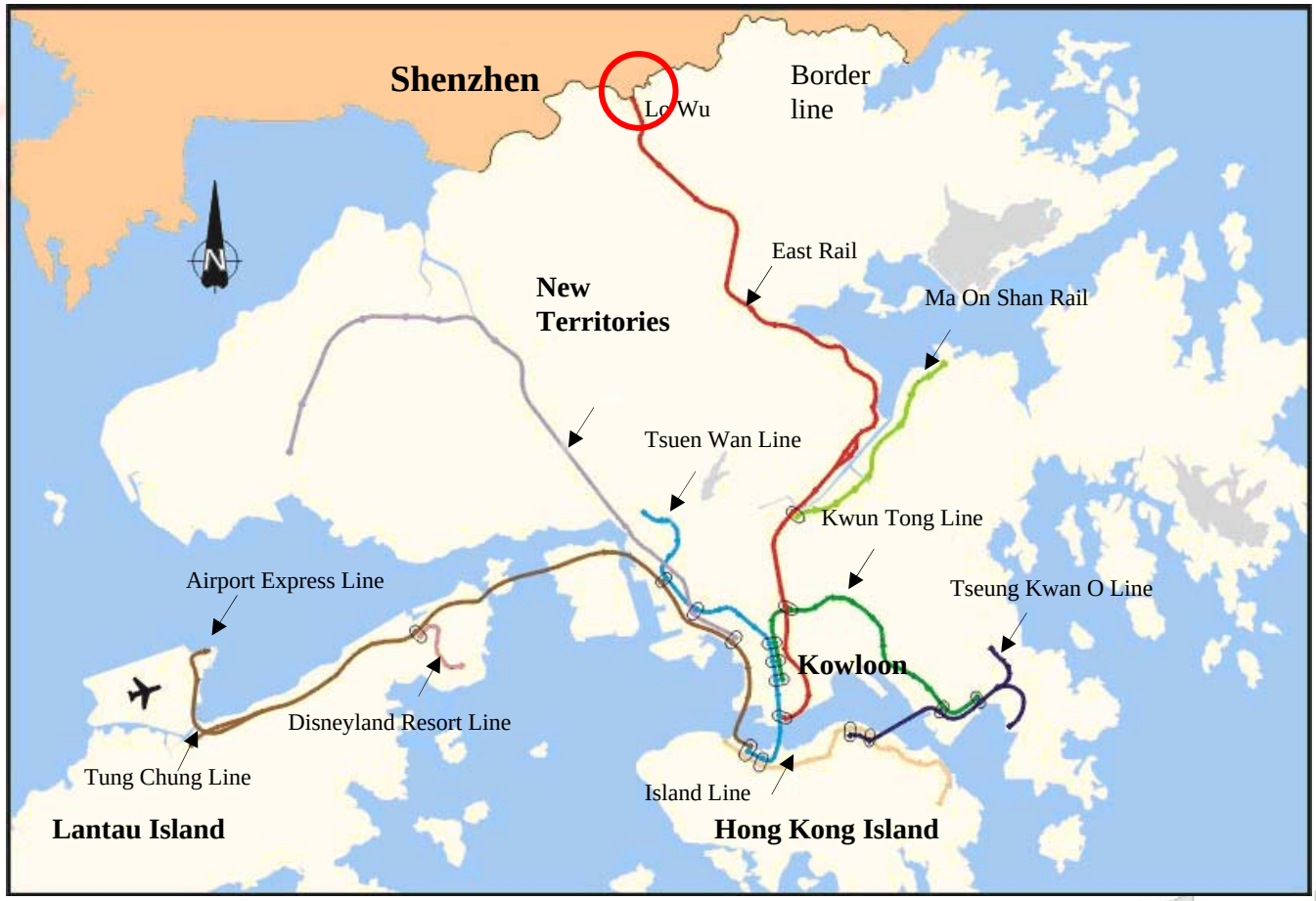
(PhD projects)

★ **Emergency Evacuation in Beijing Subway**

★ **Consultant to Taiwan High Rail System**

Railway Systems in Hong Kong

★ **Operated by two organizations which are proposed to be merged later.**



Typical New Station

- ★ **Retail Area: High Risk**
- ★ **Food and Beverage: Even Higher Risk**

Public Transport Vehicles

Accidental Bus Fire:
Burnt completely within 10 minutes

(Apple Daily)

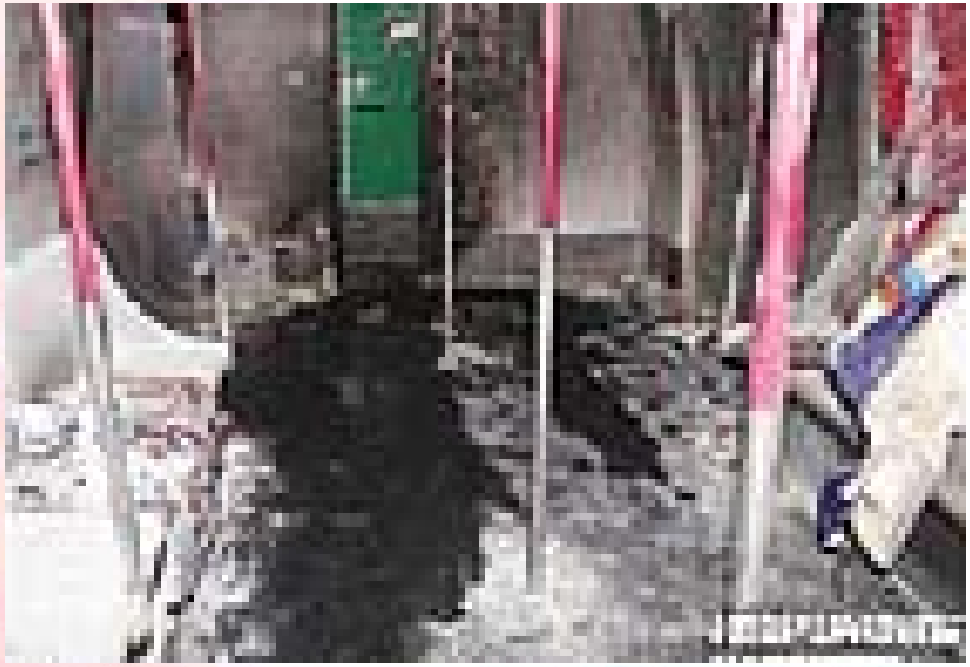
MTR Train Compartment
Arson Fire, January 2004

(Apple Daily)

Many fires

MTR Train Compartment Arson Fire, January 2004

(Apple Daily)



Key Areas Studied

- ★ **Heat release rate: > 20 MW**
- ★ **Fire retardants tested under high heat flux. (Full-scale burning test)**
- ★ **Active FSI : New concept to put in train vehicles**
- ★ **Fire Safety Management**
- ★ **Crowd Movement & Control**
- ★ **Total Fire Safety Concept**
- ★ **Smoke toxicity of materials and controlled**
- ★ **Luggage and Baggage:**
  - **East Rail to China: Heavy luggage**
  - **Others are very different**

Fire Safety Strategy for Railway Stations (Consultancy Project)

- ★ **Following CIB W014, fire safety strategy is a coherent and purposeful arrangement of fire protection and fire prevention measures which is developed in order to attain specified fire safety objectives.**
- ★ **Fire safety strategy must be clearly identified for a particular building or organization, taking into account the ways in which the building or installation is to be used, and aiming to achieve not only a good standard of fire safety but also better buildings.**

To work out a specific fire safety strategy for railway terminals, several parts have to be considered on:

- ★ **Building features;**
- ★ **Uses of the building;**
- ★ **Risk factors including the fire load density and occupant loading;**
- ★ **Materials used;**
- ★ **Hardware fire safety provisions, both passive building construction and active protection system.**

Tenability Limits Commonly Used

Any more research ?

- ★ **Radiative heat flux: 2.5 kWm^{-2}**
- ★ **[CO]: 6000 to 8000 ppm for 5 minutes exposure**
- ★ **Smoke layer temperature: 120 ^{o}C**
- ★ **Smoke layer interface height: 2.5 m**

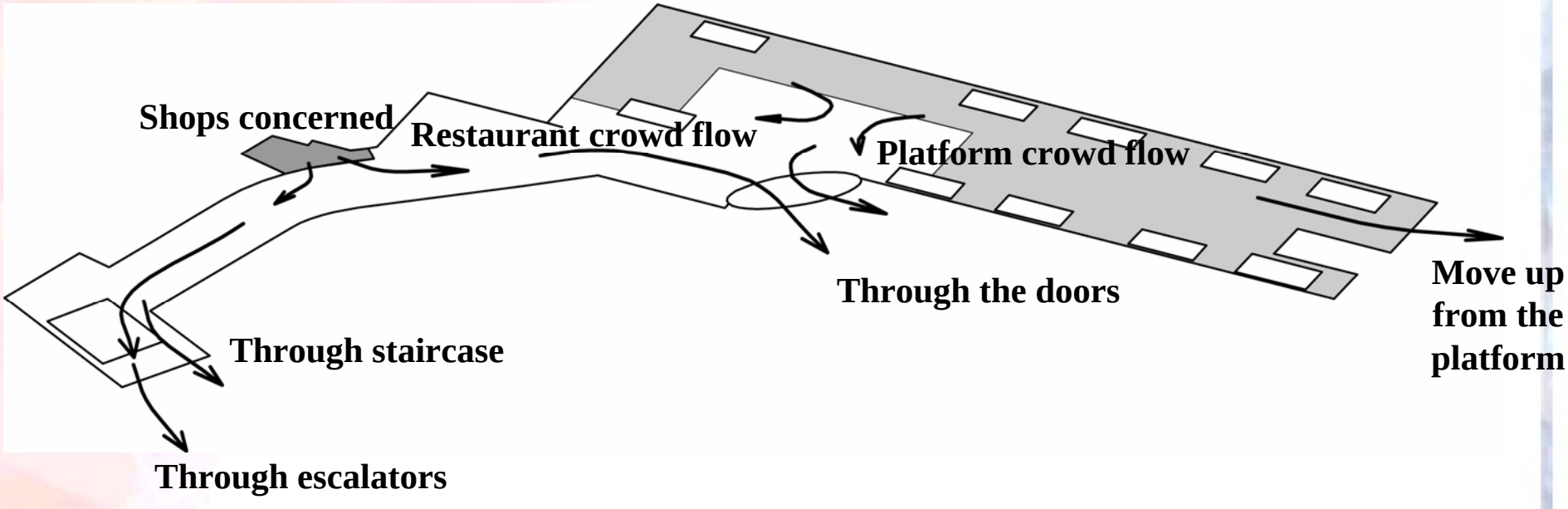
Points of Concern

- ★ Initiation of an accidental fire
- ★ Arson fire
- ★ Combustibles
- ★ Fire risks
- ★ Operation mode
- ★ Fire safety problems to be encountered
- ★ Terrorist Attack

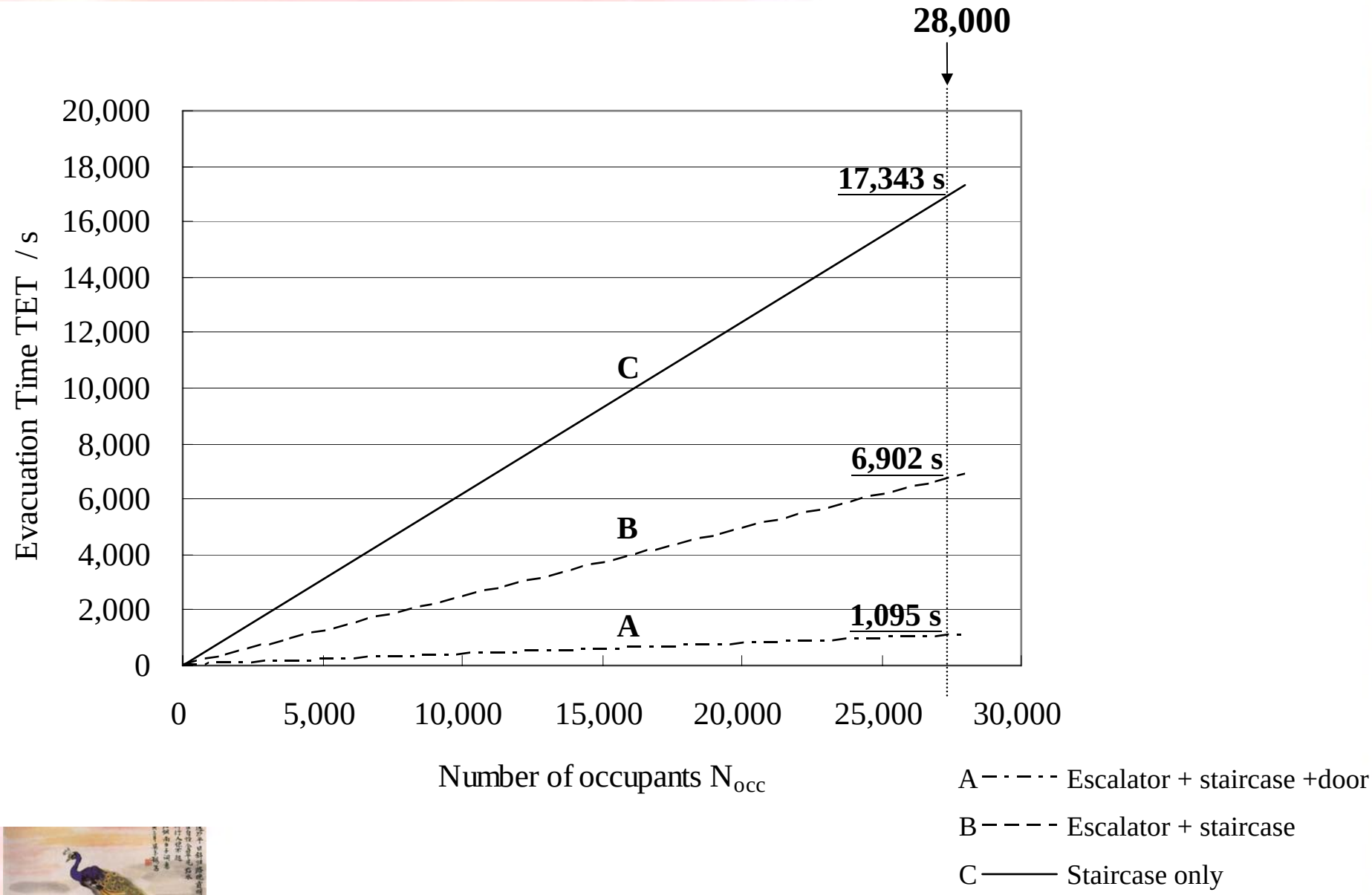
An Example Station

Consultancy on changing Retail Shop to Restaurant

To be a restaurant



Crowd flow interaction



Evacuation time under different occupant loadings

5. Research Plan Proposed by the Principal Author

- ★ **Taking NIST-BFRL research programme, such as for the BART, the 3-stage process : Materials; Fire Model; Full-scale Burning.**
- ★ **Put in characteristics in China are :**

Heavy occupant loading :

- Zhangzhou incidence in 2006
- Photos of crowd during the Spring Festival

High fire load density :

- Combustible content, high heat release rate, smoke toxicity

- ★ **Extend the NIST-BFRL 3-stage research programmes by the item on Active Systems; Compartment Design and Fire safety Management.**

Supported by funding earnt by consultancies

★ **Total Fire Safety Concept**

Passive :

- **Compartmentation in different train vehicles, 'non-combustible' as in Hong Kong (though the term has to be defined**
- **Flame spread**
- **Materials selection**
- **Evcauation pattern**

Active :

- **Quick detection, rapid suppression, removal of contaminants including steam (Some subway used to claim this point so that sprinkler not installed !)**
- **Actuation time should be later than evacuation time,**
- **Quite opposite to what include actuation time to cut off heat release rate to extend evacuation**

Fire Safety Management : Software to control hardware, with demonstration by burning tests, NOT just calculation !

Review on the Fire Safety Strategy

★ **Fire safety strategy on railway lines should be worked out by the total fire safety concept.**

Hardware ← Provide safety ← **Software**

- Passive construction design
- Active FSI

- FSM

Suggested Research Topics

- ★ To investigate the smoke toxicity in burning the different materials and luggage inside the train compartment;
- ★ To study the effect of the special structures inside the train compartment on fire growth;
- ★ Acoustics; mechanical ventilation;
- ★ To study systematically the fire behaviour of different decorative materials inside the train compartment;
- ★ Fire model on smoke control;
- ★ Fire and smoke control measures for high speed trains.

- ★ **Experimental studies will be carried out, together with theoretical analysis and field modelling, to study the causes of fire, danger characteristics, smoke movement inside the train compartment, smoke control measures, fire prevention and suppression measures and evacuation for high speed passenger trains with speed over 200 km/h;**
- ★ **To propose fire prevention schemes in high speed passenger trains;**
- ★ **To provide scientific support for drafting the design code for fire safety of high speed passenger trains《高速旅客列车防火设计规范》.**

Studying Heat Release Rate is Essential

- ★ **Different values were used by the designers in the past:**
  - **Terminal hall: up to 7 MW**
  - **Shopping mall: 5 MW**
  - **Atrium: up to 7 MW**
  - **Train compartment: 1 MW**

- ★ **Full-scale burning tests on local products are essential.**

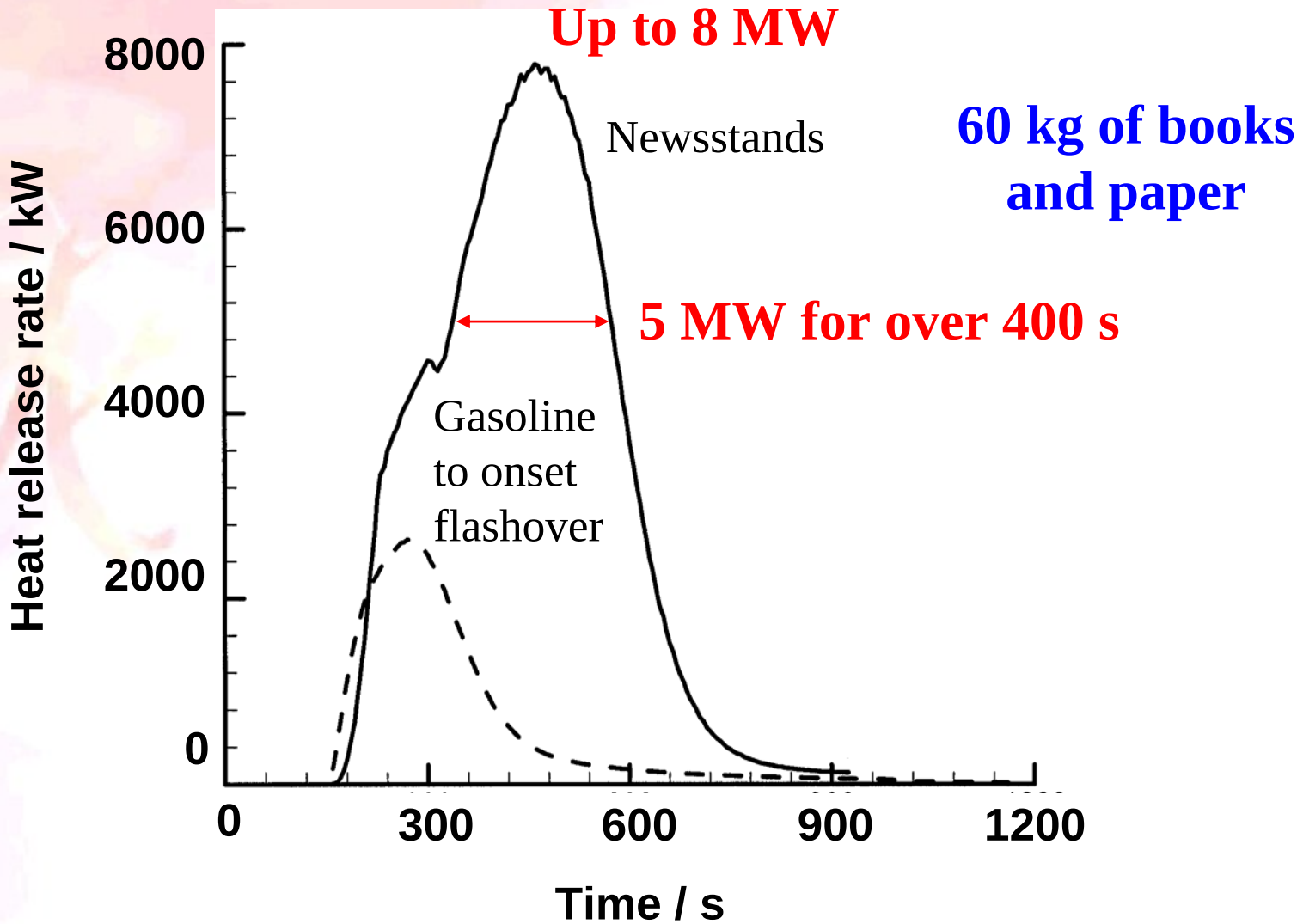
Research Partners

呼蘭河之西

黑龍江省

Heilongjiang Province

Onset flashover



★ **Consequences of such a big retail shop fire in a big atrium or public transport interchange should be watched carefully.**

6. Conclusion

- ★ **Research on High Speed Train in China is necessary.**
- ★ **Funding earnt by consultancy.**
- ★ **Physical : Bench-scale with cone calorimeter**

  Full-scale burning

- ★ **Method : fire modeling**

  CFD/zone model

- ★ **Active systems : Quick Detection, Quick Suppression, Exhaust**
- ★ **Fire Safety Management**
- ★ **Effects on Railway Stations and Tunnels**