ODD: London Euston Station Fire Evacuation Modelling

The model description follows the ODD (Overview, Design concepts, Details) protocol for describing individual- and agent-based models (Grimm et al. 2006), as updated by Grimm et al. (2020).

1. Research Question

Fire safety and evacuation plan are important for public places, which includes staff training, emergency doors and lighting setting etc. as UK government mentions (GOV.UK, 2023). So, how exactly do different levels of fire evacuation plan affect the evacuation effect during emergencies? In this model, staff and route setting will be focused on and two research questions are proposed:

a. How fire awareness of staff affects evacuation effect?

b. How emergence exits and lighting setting affects evacuation effect?

London Euston Station is selected as modelling object.

2. ODD Description

Overview: 2.1-2.3

2.1 Purpose and patterns

The specific purpose of model is to understand and predict how different fire evacuation setting in public places affect final evacuation effect, which focusing on fire awareness of staff, number of exits and whether there is an emergency lighting. Specifically, the model could be evaluated by three patterns:

a. High-quality Fire Safety

High-fire-awareness staff, adequate emergency exits, emergency lighting setting.

b. Medium-quality Fire Safety

Uneven-fire-awareness staff, normal emergency exit, without emergency lighting setting.

c. Poor-quality Fire Safety

Low-fire-awareness staff, few emergency exits, without emergency lighting setting.

2.2 Entities, state variables, and scales

Entity in this model is divided into two categories: turtles and patches, of which the turtles are subdivided into five breeds. Patches are set in different colors to represent different areas of Euston Station. Turtles are classified as passengers, fire spots and three types of staff with different fire awareness level.

Following Grimm et al (2020)'s Overview Design Details (ODD) structure describing the state variable as 'the minimum information you must save', the states variables of global, patches and turtles of Euston Station Model are as Table 1.

Table 1 State Variables of Euston Station Model

`		Variables Name	Description	Type	Units	Static or Dynamic	Range or Value
Global		num-passenger-waiting-hall	Initialized number of passengers that in waiting hall.	Int	person	Static	[300, 500]
		num-passenger-store	Initialized number of passengers that in stores.	Int	person	Static	[50, 80]
		num-staffs-high-awareness	Initialized number of different staff	Int	person	Static	[0, 10]
		num-staffs-medium-awareness		Int	person	Static	[0, 10]
		num-staffs-low-awareness		Int	person	Static	[0, 10]
		fire-started?	Whether fire occurs.	Boolean	\	Dynamic	true / false
		fire-occur-time	Ticks that fire occurs.	Int	tick	Static	200
		exit3-open?	Whether the exit is open.	Boolean	\	Dynamic	true / false
		exit2-open?		Boolean	\	Dynamic	true / false
		exit1-open?		Boolean	\	Dynamic	true / false
		emergency-lighting?	Whether the emergency lighting is existing.	Boolean	\	Dynamic	true / false
Patches		fire?	Whether fire has arrived this patch.	Boolean	\	Dynamic	true / false
		staffonly?	Whether only staff can reach.	Boolean	\	Static	true / false
		accessible?	Whether agents can reach.	Boolean	\	Static	true / false
		dist-exit1 dist-exit2 dist-exit3	Distance to three exits.	Int		Dynamic	Various
		selected1? selected2? selected3?	Whether has been setted distance attribute.	Boolean	\	Dynamic	true / false
Turtles	breed [staffs-medium-awareness staff-medium] breed [staffs-low-awareness staff-low] breed [staffs-high-awareness staff-high]	panic-degree	Initialized panic degree	Int	Interval = 1	Dynamic	High: 1 Medium: 3 Low: 4
		health-condition	Initialized health condition	Int	Interval = 1	Dynamic	[0, 5]
		reaction-time	Time between reaction and action after fire occurs	Int	Interval = 1	Dynamic	High: 1 Medium: 2 Low: 3
	breed [passengers passenger]	panic-degree	Initialized panic degree	Int	Interval = 1	Dynamic	[0, 8]
		health-condition	Initialized health condition	Int	Interval = 1	Dynamic	[0, 5]
		reaction-time	Time between reaction and action after fire	Int	Interval = 1	Dynamic	5
		calmed?	Whether has been calmed by staff after fire occuring.	Boolean	\	Dynamic	true / false
	breed [fire-spots fire-spot]	\	\	\	\	\	\

One time step represents 4-5 seconds in this model, which there is no specific stop time but when the number of evacuees is constant, the simulation is over by default. Each patch represents approximately 1 meter in real word and the total layout of patches is 64 * 32.

2.3 Process overview and scheduling

Process: The model is structured in mainly 6 processes: two each for passengers, staffs and fire. In each updated tick, about 4-5 seconds have passed in the modeled world. Before the fire, passengers and staff move at a set speed within a designated area, without a clear direction. After fire, most passengers head to, but the "panic" passengers continue to move aimlessly. Staff first execute the evacuation task to help passengers, and start their own escape only after 100-time steps.

Scheduling:

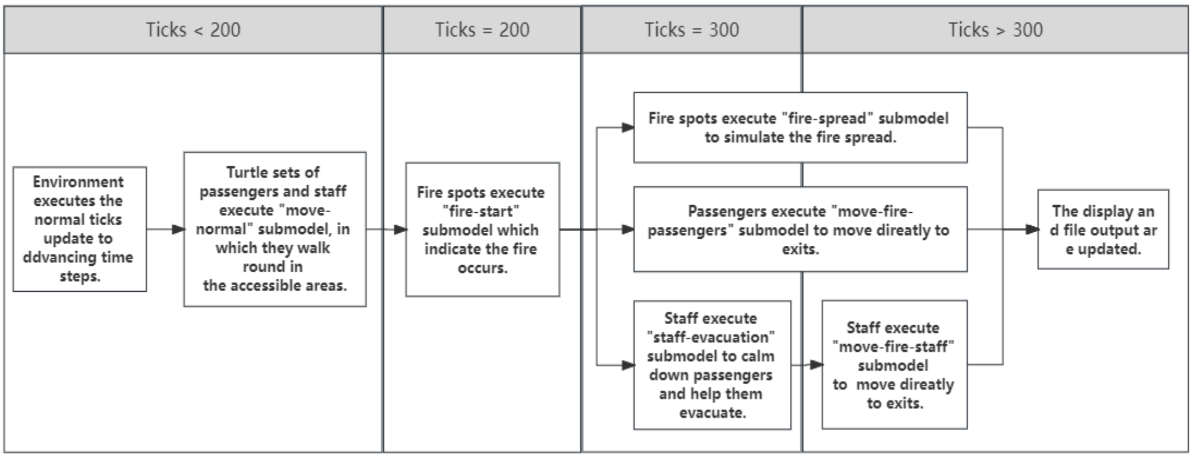


Figure 1 Scheduling of Euston Station Model

Design Concept: 2.4

2.4 Design concept

2.4.1 Basic Concept

This model simulates a classic scenario of social emergency known as fire evacuation based on individual reaction. This modelling approach is based on multiple studies acknowledging the perception of evacuees when facing emergency (Gershon et al., 2007) Day et al., 2013). Specifically, this model relates to the following theories related to human behavior:

a. Risk perception (RP)

RP refers to the perception of the imminence of one's life, which is a mental state description. In this model, *variable "panic-degree"* represent this theory (Kinateder et al., 2015). And some studies suggest that improving signage systems can effectively guide evacuees and increase evacuation effect(Akizuki et al., 2009) (Xie et al., 2012). Therefore, *emergency lighting chooser* in interface is set.

b. Behaviour Sequence Model

This model was propose by Canter (1980) which refers to three steps that individuals typically take in sequence when facing a fire: "interpret", "prepare" and "act". In this model, *variable "reaction-time"* is designed to represent the first two steps before officially evacuating.

c. Role-rule Model

Canter's theory also demonstrates that the reaction is vary from different roles, which staff always be the guiding role. A study of the 1987 King's Cross Station Fire also indicates that staff with different abilities or roles have different guiding capabilities. Therefore, *"staff-evacuation" submodel* and *three breeds about staff* with different fire awareness are designed.

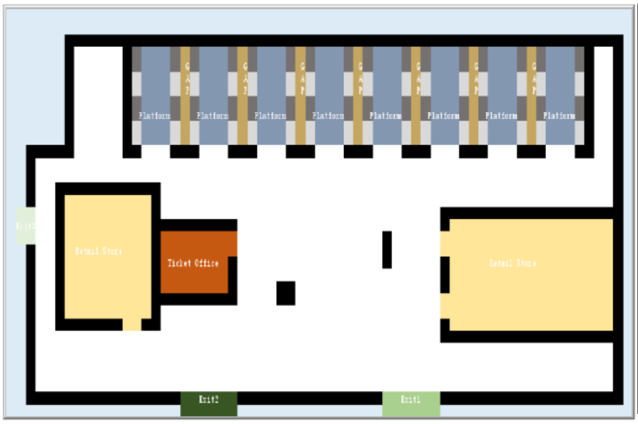
2.4.2 Adaption and Sensing

The adaptive behavior of passengers and staff is to relocate the patches that can go and should go. Before fire, they go to the patches that available, and once fire starts, they purposefully head to the patches that closest to exit. The sensing behavior of fire is to sense whether the neighbouring patches are on fire and to decide whether itself also on fire, which is also a kind of adaption (Grimm et al., 2020).

Details: 2.5-2.7

2.5 Initialisation

In this model, which simulates a specific public space, the important layout is established using patches. Euston Station layout is obtained from National Rail website, and different colors represents different types of areas (Figure 2). Passengers from train are not investigated in this model, so the variable "accessible?" for trains are false.



	Type	color	Attribute	distance to exits
Patches	Waiting Hall	White	staffonly? false accessible? true	Calculating "dist-exit1", "dist-exit2", "dist-exit3 for each patches.
	Retail Stores	Light yellow	staffonly? false accessible? true	
	Ticket Office	Red	staffonly? true accessible? true	
	Exits	Green	staffonly? false accessible? true	
	Platform	Blue	staffonly? false accessible? true	
	Train	Grey & light grey	staffonly? false accessible? false	\
	Buildings	Black	staffonly? false accessible? false	\
	Background	Light blue	staffonly? false accessible? false	\
	Gap between trains	yellow	staffonly? false accessible? false	\

Figure 2 Initialisation of Patches

A certain number of breeds are created at the beginning and the exact number can be adjusted by sliders, which the color of passengers and staff are set brown and blue respectively. Some global variables are also set as Figure 3.

	State Variables	Turtle Sets	Value
Turtles	panic-degree	breed [staffs-high-awareness staff-high]	1
		breed [staffs-medium-awareness staff-medium]	3
		breed [staffs-low-awareness staff-low]	4
		breed [passengers passenger]	random 8 + 1
	health-condition	breed [staffs-high-awareness staff-high]	5
		breed [staffs-medium-awareness staff-medium]	5
		breed [staffs-low-awareness staff-low]	5
		breed [passengers passenger]	5
	reaction-time	breed [staffs-high-awareness staff-high]	1
		breed [staffs-medium-awareness staff-medium]	2
		breed [staffs-low-awareness staff-low]	3
		breed [passengers passenger]	5

	Variables Name	Range or Value
Global	num-passenger-waiting-hall	400
	num-passenger-store	80
	num-staffs-high-awareness	5
	num-staffs-medium-awareness	5
	num-staffs-low-awareness	5
	fire-started?	false
	fire-occur-time	200
	exit3-open?	true
	exit2-open?	true
	exit1-open?	true
	emergency-lighting?	true

Figure 3 Initialisation of Turtles and Global

2.6 Input Data

The model does not use input data to represent time-varying processes.

2.7 Submodel

The whole Euston Station fire evacuation model can be divided into six submodels, whose execution sequence is shown in Figure 1. And the model is designed following several rationales:

a. Individuals experience fear when facing a fire, and generally, passengers are more fearful than staff.

b. Trained staff have the responsibility to instruct passengers to evacuation.

c. Staff have clear job responsibilities, so there is generally no movement between those inside and outside the ticket office.

Table 2 Complete Submodel Description

	No.	Name	Description
Euston Station Fire Evacuation Model	Sub1	move-normal	Including the move pattern of both staff and passengers before fire. For passengers, they can go to the all patches that accessible? is true except for ticket office. For staff, those initially in the ticket office stay there, while those initially out do not enter. Both of them move to one of 4 surrounding patches that meet the requirements.
	Sub2	fire-start	When time step reaches 200, fire occurs in one of the patches that accessible? is true. A boolean variables fire-started? is used to guarante this submodel run only once.
	Sub3	fire-spread	Patches can sense whether there is fire in surrounding 4 patches, if there is, the variable "fire?" of this patches become true. Only one patch is changed each tick.
	Sub4	move-fire-passengers	When fire occur, move pattern of passengers changes and panic start. Reaction-time is firstly checked, when it is smaller thatn 0, most passengers start to head to exits that closest while some passengers with the panic-degree higher than 4 will go random. If there is staff in the 4 surronding patches, passengers will be calmed and the panic-degree will decrease 1, but every passenger can only be calmed once.
	Sub5	staff-evacuation	When fire occur, staff will experence a reaction time as passengers. When the reaction-time smaller than 0, staff start to instruct passengers to evacuate in waiting hall (staff in the ticket office are also) and they will not outsied the station at that time. This procedure will last 100-time steps (ticks).
	Sub6	move-fire-staff	Once "staff-evacuation" is over, staff start to head to exits for evacuation.

3. Brief Methodology

The research question focuses on the impact of different staff qualities, the number of emergency exits, and the presence or absence of emergency lighting on evacuation efficiency. Therefore, basic experiments for each of the three subjects should be performed.

Table 3 Experiments for Each of Three Subjects

Experimental Parameter	Experiments	Experimental Value	Notes	Iterations
Staff	Experiment1	num-staffs-high-awareness = 5 num-staffs-medium-awareness = 5 num-staffs-low-awareness = 5	Control group for staff experiment	10
	Experiment2	num-staffs-high-awareness = 0 num-staffs-medium-awareness = 5 num-staffs-low-awareness = 5		10
	Experiment3	num-staffs-high-awareness = 5 num-staffs-medium-awareness = 0 num-staffs-low-awareness = 5		10
	Experiment4	num-staffs-high-awareness = 5 num-staffs-medium-awareness = 5 num-staffs-low-awareness = 0		10
Exits	Experiment5	Set exit3? off	Through switch in the interface	10
	Experiment6	Set exit3? and exit2 off		10
Emergence Lighting	Experiment6	Set emergency-lighting? off		10

The control group for both six experiments is the model in the initial state in 2.5. To answer the research question, results of evacuee numbers should be compared, which includes total and each exit, and the plots setting in the interface can give a visual analysis.

In fact, this model can be used to explore more scenarios. For example, influence of the number of passengers or staff on evacuation efficiency and the scenario of a train arrives. Even further, it can be combined with multi-level evacuation models to explore Euston Station fire evacuation model that include underground and mezzanine floors.

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