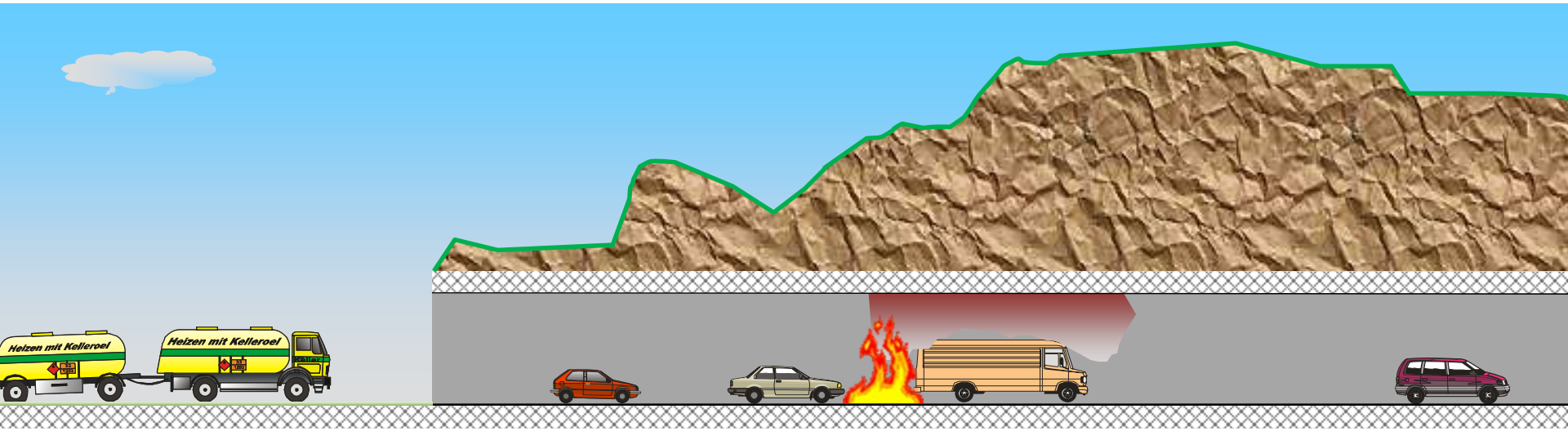
Evacuation in tunnel

human behaviour,
tunnel ventilation
and more…



Norwegian Tunnel Safety Conference 2018

Dr Rune Brandt, HBI Haerter, Switzerland

Human behaviour – in case of fire in a tunnel

General

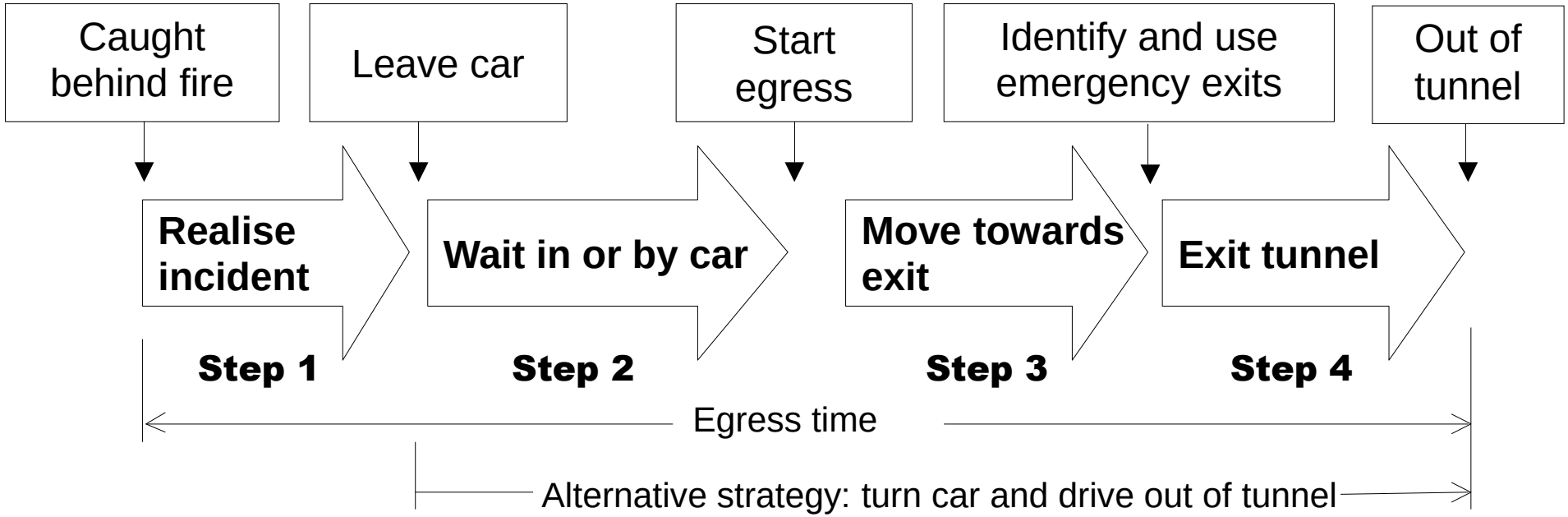
1. Rational
2. Assisting / helping
3. No panic
4. Behave as usual
5. Accept instructions from person of authority (police, emergency service, …

Egress phases (control centre) and egress steps (user)

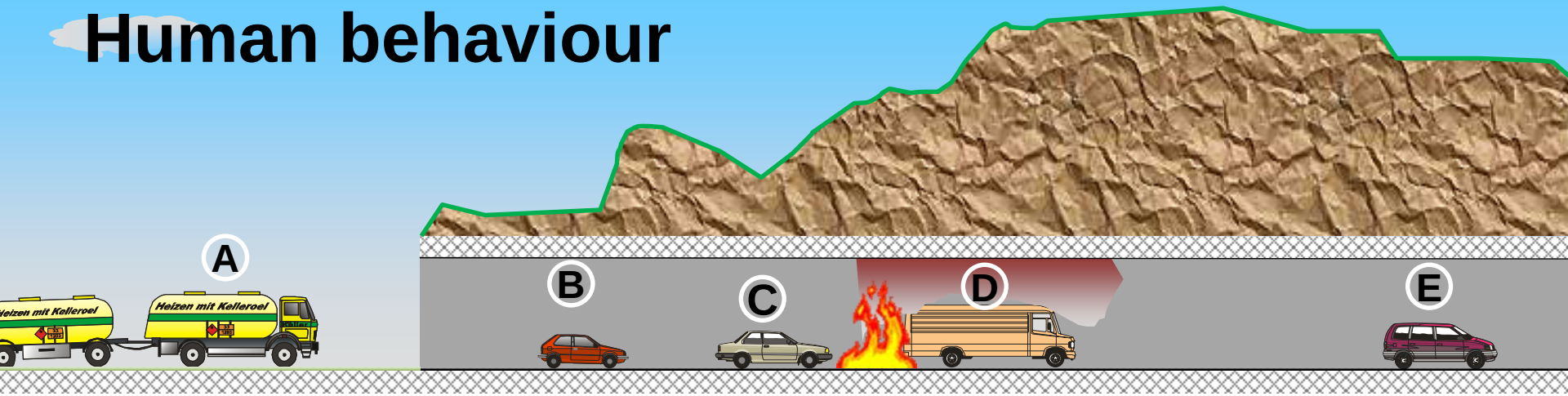
Phases according to **reactions in control centre**

a) Detection phase: time to detect incident
b) Alarm phase: time to evaluate proper response
c) Action phase: time to at activate response
d) Egress phase: time to evacuate all users

Egress steps see from the **users perspective**



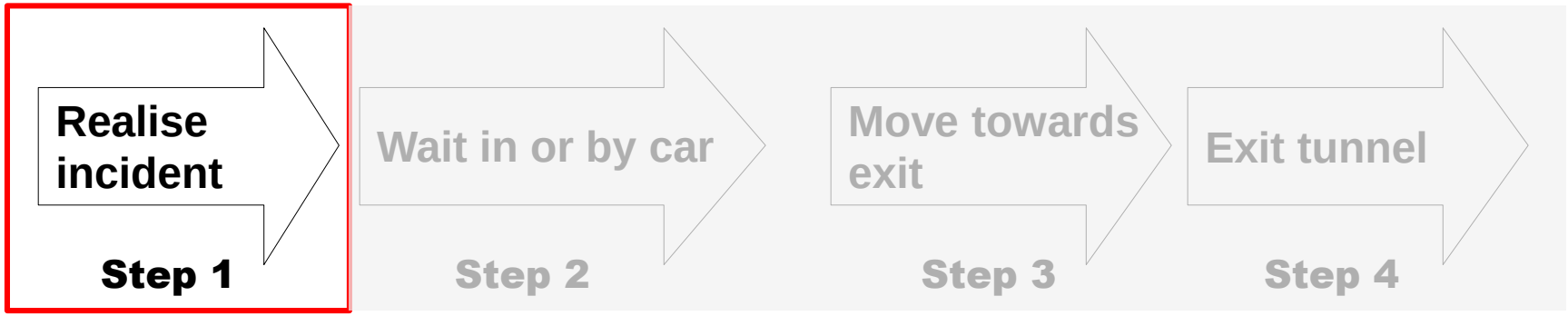
Human behaviour



Position	Ideal behaviour	Condition	Likelihood
A	Stop outside tunnel	No tunnel closure	~0%
		Tunnel closure with barrier	~100%
B	Stop and evacuate by food	See smoke/fire	~10%
		See smoke/fire and radio/sign info	~50%
C	Evacuate by food	See smoke/fire	~40%
		See smoke/fire and radio/sign info	~50%
		Directions by person of authority	~100%
D	Stop and evacuate by food	Captured in smoke	~30%
		Captured in smoke and radio/sign info	~40%
		Directions by person of authority	~100%
E	Drive out	No instructions to do otherwise	~100%

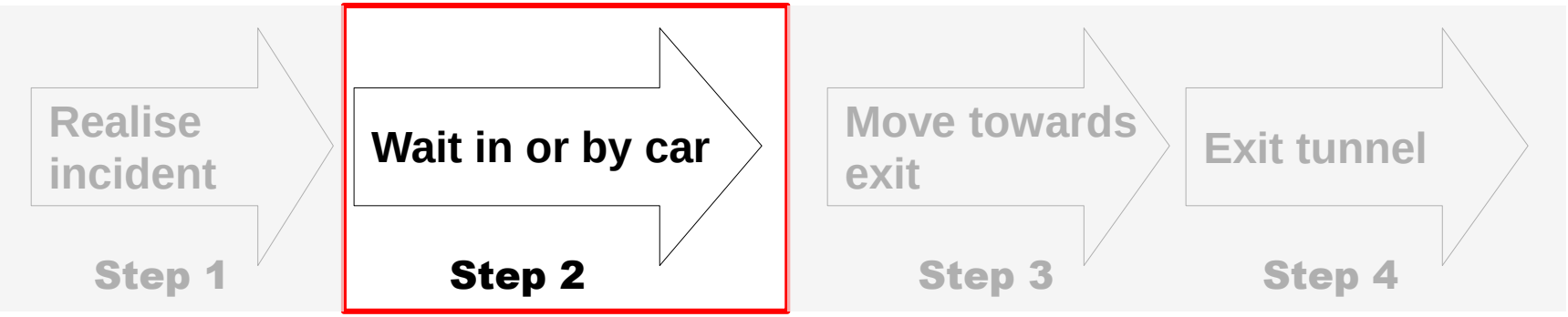
Step 1: realise incident

- Typically, **several minutes** (2/3 of the total available egress time) **is wasted during this step** without the user moving anywhere
- It is **difficult** for the user to **differentiate** a **fire** from a **normal traffic incident** e.g. congestion and standstill
- Users often need **information from different sources** to realise that it is a critical situation
- There are **large individual differences** on which type and amount of information that is required
- **Short and easy understandable messages are beneficial**



Step 2: Decision making and preparation of egress

- **The fires** potential **growth rate** is **under estimated**
- **Several minutes** can be used to **discuss** the situation with **other users**
- Some user start to **extinguish the fire;** but these stop doing so and commence evacuation if they feel that they are in danger
- **Evacuation in groups**, which extents the egress time
- Only evacuation **through smoke,** if users are **convinced** that this will lead them to an **emergency exit**



Improvement of Steps 1 and 2: Information

SLASS – Synchronised Longitudinal Announcement Speaker system

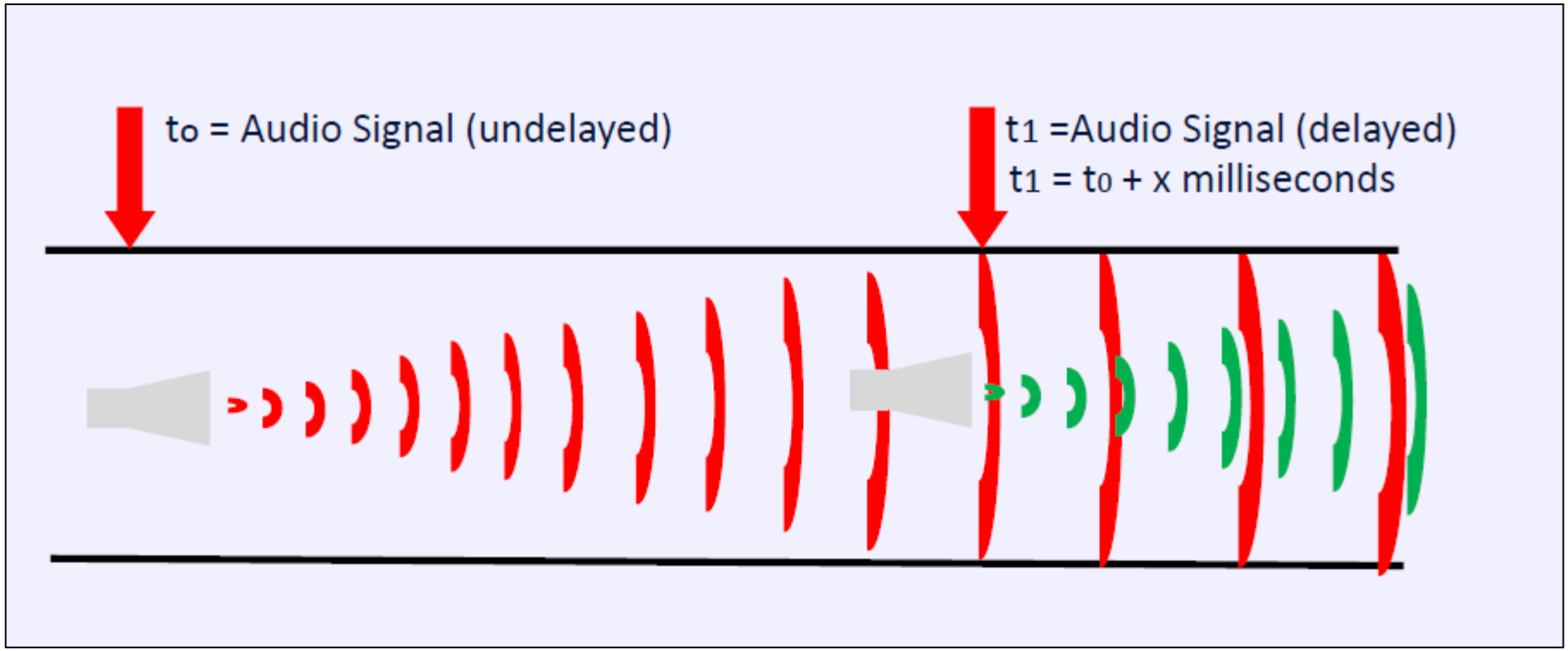
Realise incident — **Step 1**

Wait in or by car — **Step 2**

Move towards exit — Step 3

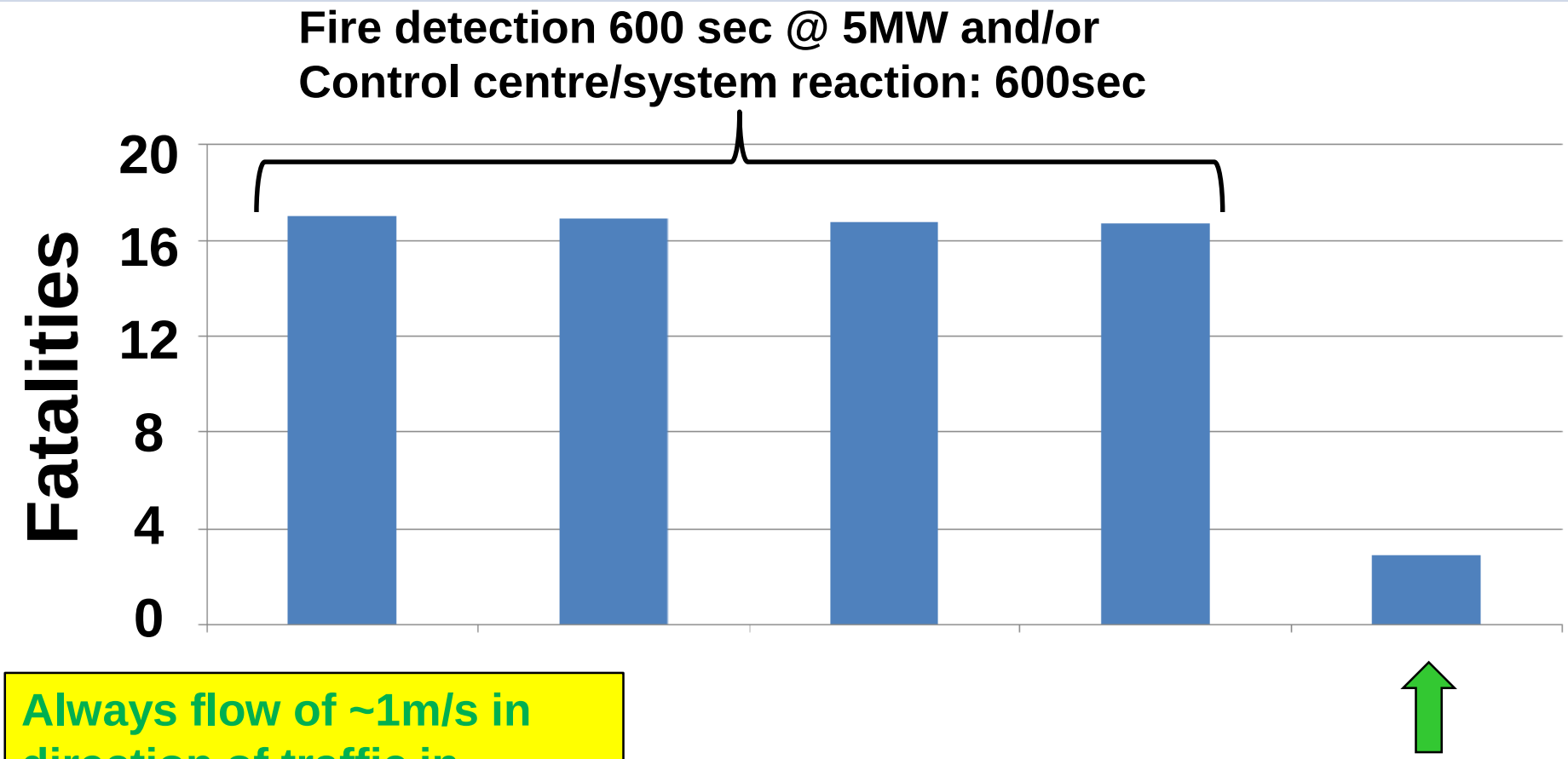
Exit tunnel — Step 4

SLASS – Synchronised Longitudinal Announcement Speaker system



Improvement of control centre: detection and alarm phase

Reduce consequence by having a minimum tunnel ventilation at all times



Always flow of ~1m/s in direction of traffic in unidirectional tunnels as mitigation measure for slow fire detection.

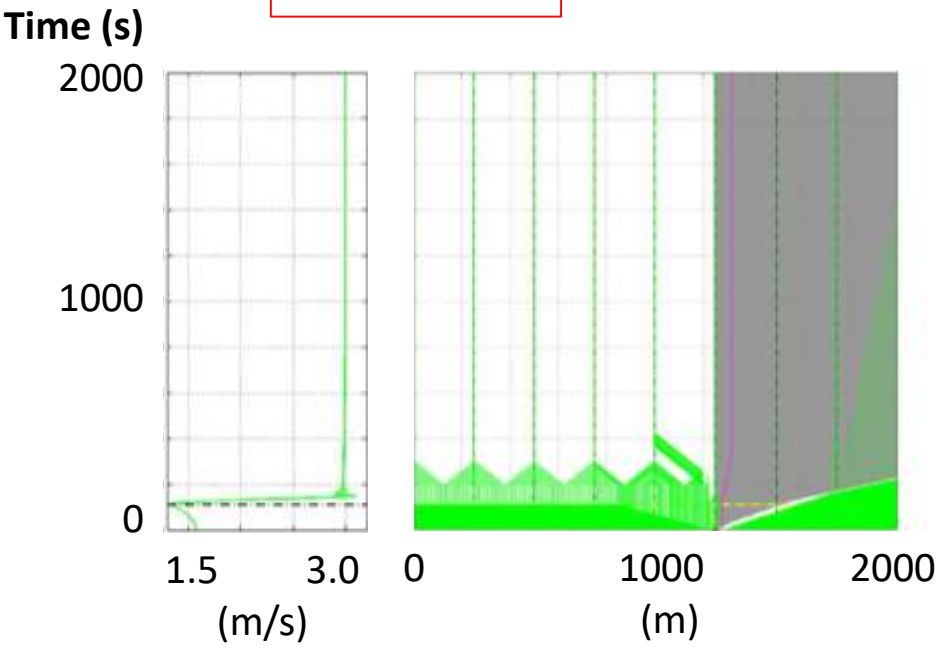
Fire detection 60 sec @ 5MW
Control centre / system reaction: 20sec

Improvement of control centre: detection and alarm phase

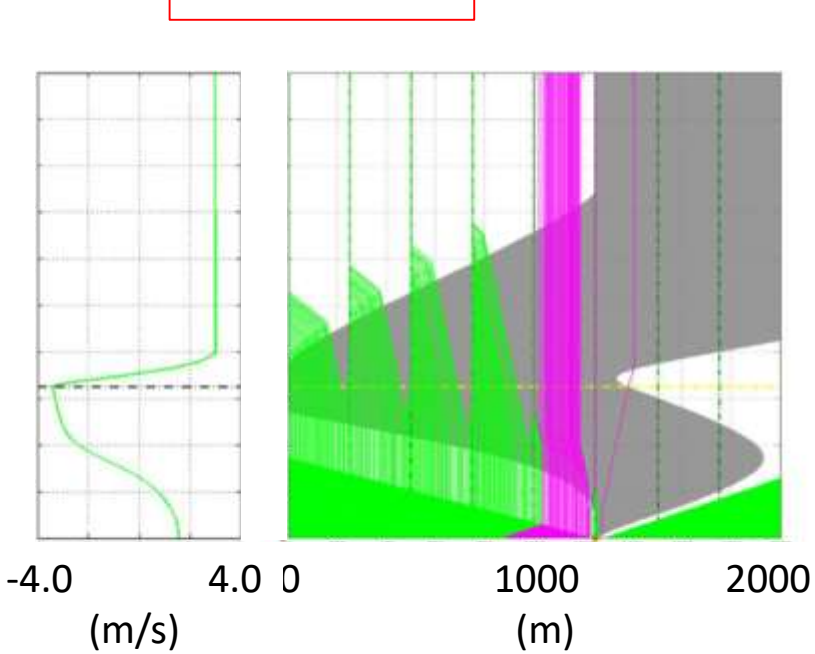
Reduce consequence by having a minimum tunnel ventilation at all times

Reduction of sensitivity of speed of fire detection and reaction time by control centre

Fast detection



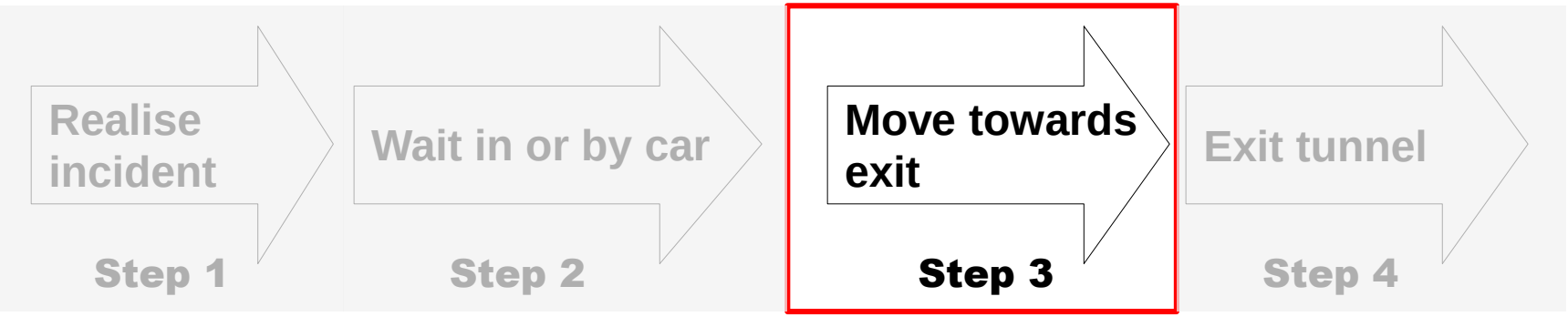
Slow detection



rapid tunnel closure = minimise impact

Step 3: move towards exit

- Tendency to **evacuate backwards from the way** that the user came from
- Tendency to at **turn car** if **visibility** is **less than 10m**
- Users that have reached a safe haven are **prepared to re-enter the zone of danger**
- Egress speed 0.3m/s (no visibility) to 2m/s; mobility impaired down to 0.17m/s.



Bi-drectional traffic

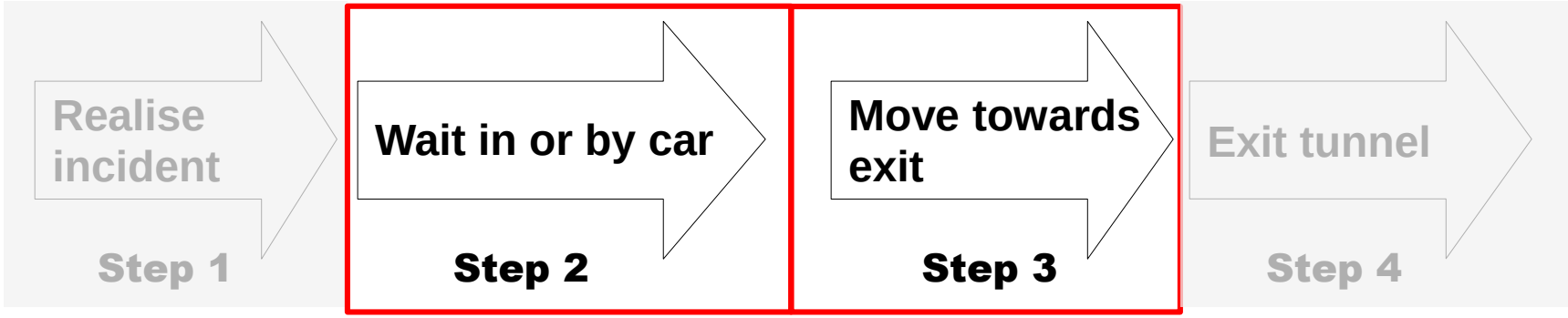
Snu og køyr ut / turn car and drive out

- Assumption NordFou-project:
  60 s to turn car
  Speed in smoke : 2 m/s = 7 km/t
- Alle cars could exit the tunnel without coming in a critical situation

- Problems:
  - Large vehicles cannot turn and hence blocks the passage for other cars
  - Collision with tunnel wall
  - Impact with user egressing by foot

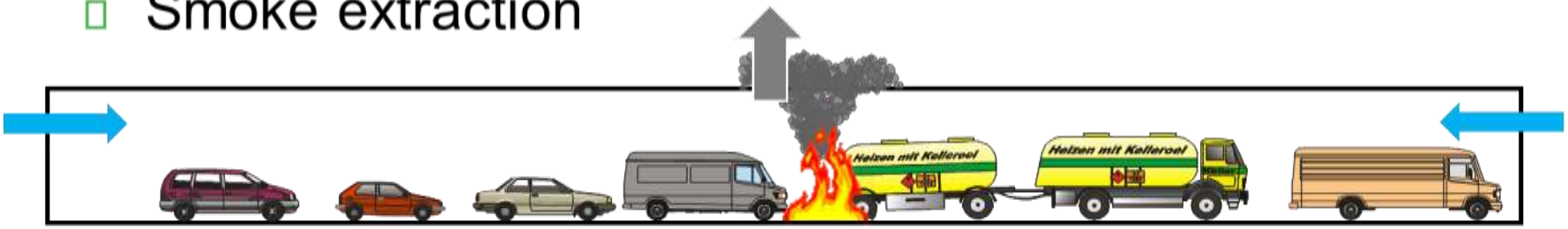
Lights provides guidance and reduces risk of incidents

Guidance lights and illuminated egress signs

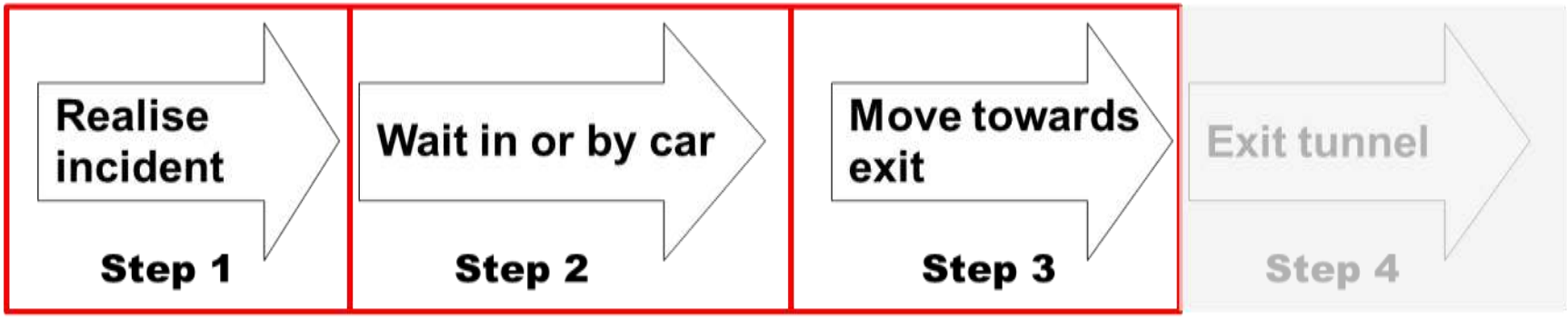


Steps 1 to 3: how to gain time

- Smoke extraction



- Longitudinal ventilation (no cars/persons downstream)

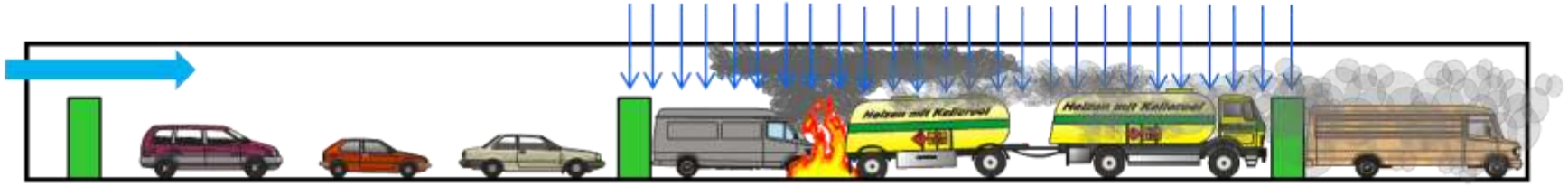


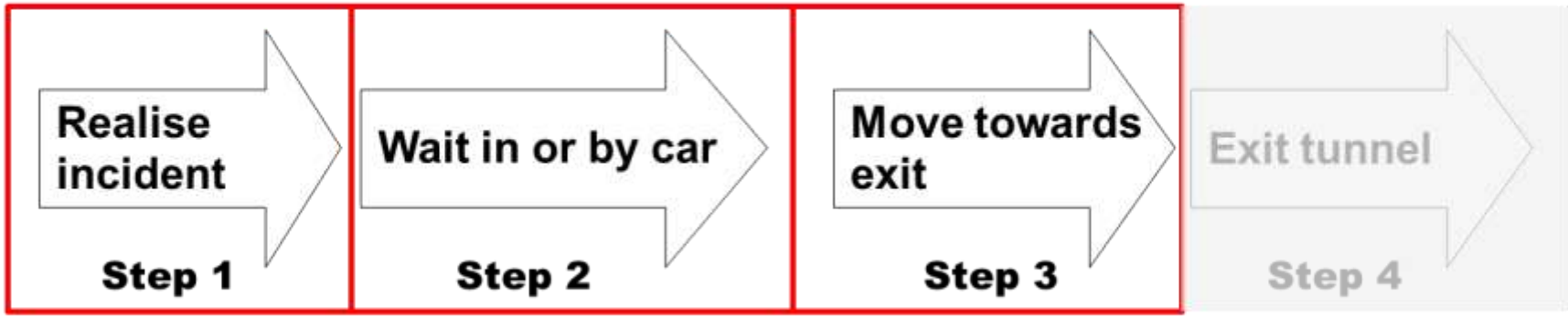
Smoke management when cars/persons on both sides of fire

Steps 1 to 3: how to gain time

- Smoke extraction, large distance between emergency exits

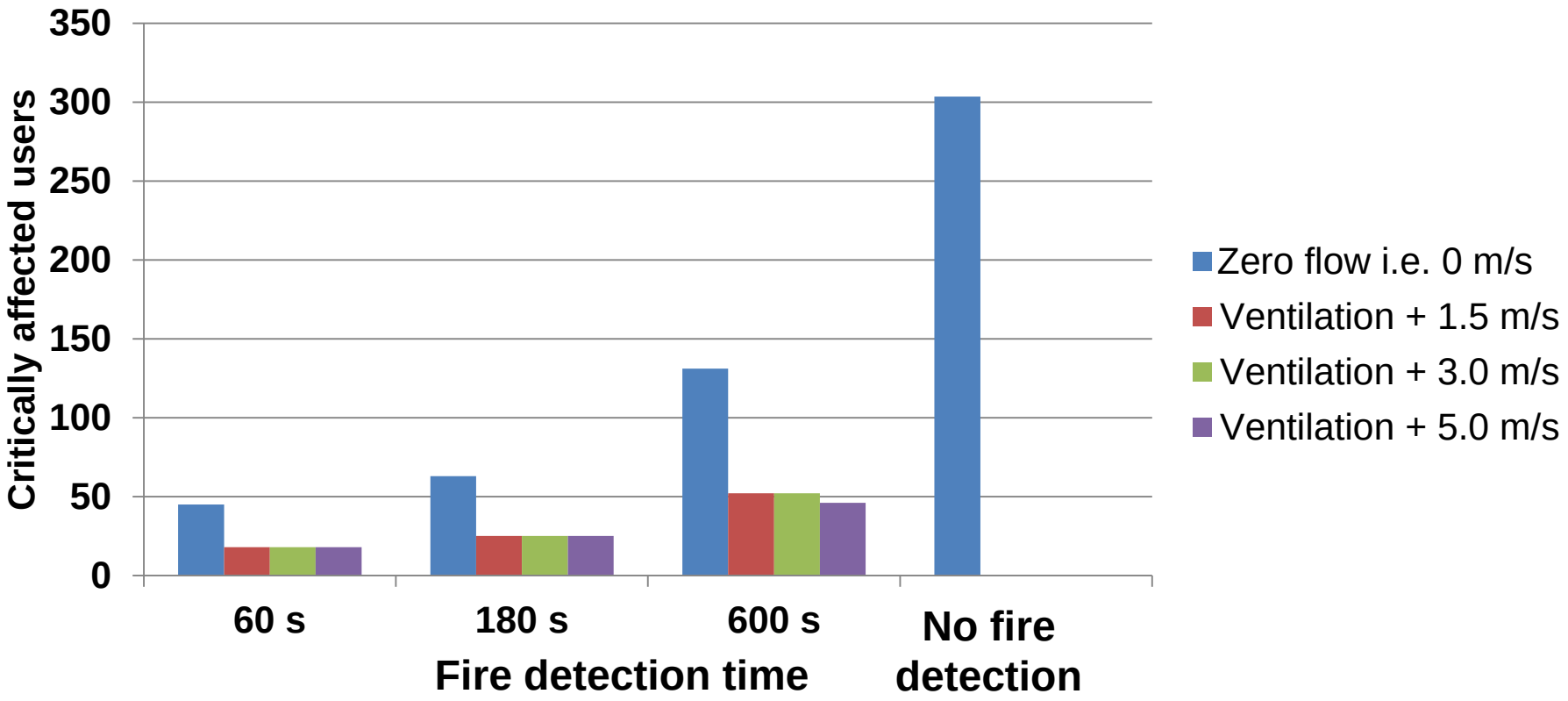
- Longitudinal ventilation, short distance between emergency exits and fixed fire fighting system





Tunnels with bi-directional trafic

Longitudinal ventilation: rapid activation and high speed is advantageous



- **Short detection- and response time is important**
- **Ventilation reduces the effects**

Smoke management in single-tube tunnel with bi-directional traffic

Which measures are efficient to minimise the potential fatalities?

Tunnels with one tube and bi-directional traffic:

- Often low equipment level
- Low traffic numbers
- Perhaps long
- Perhaps high longitudinal slopes

Smoke management in single-tube tunnel with bi-directional traffic

Longitudinal ventilation: equality, stratification and/or dilution?

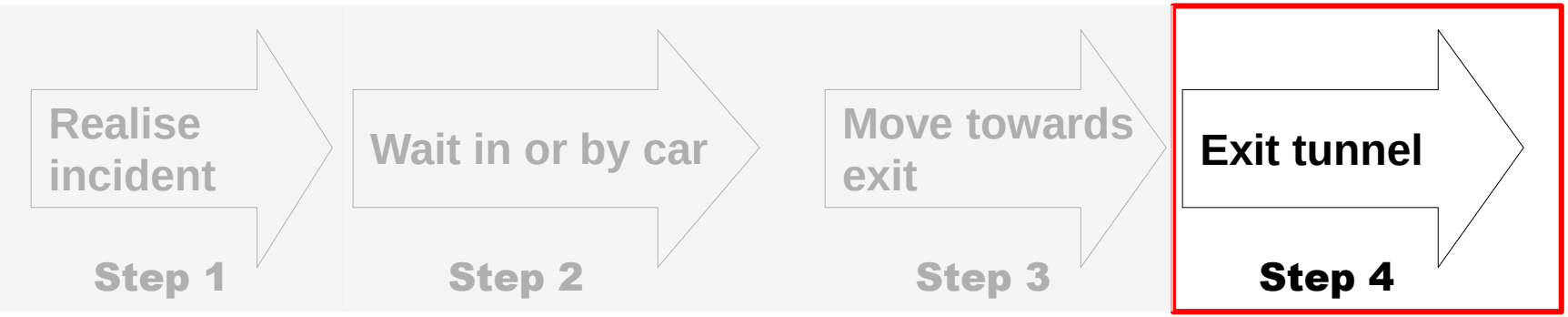
Minimise speed of smoke spread, high CO concentrations: Japan

Reduce CO concentrations and retain favourable conditions for smoke stratification

Smoke spread only in one direction, smoke dilution: simple strategy

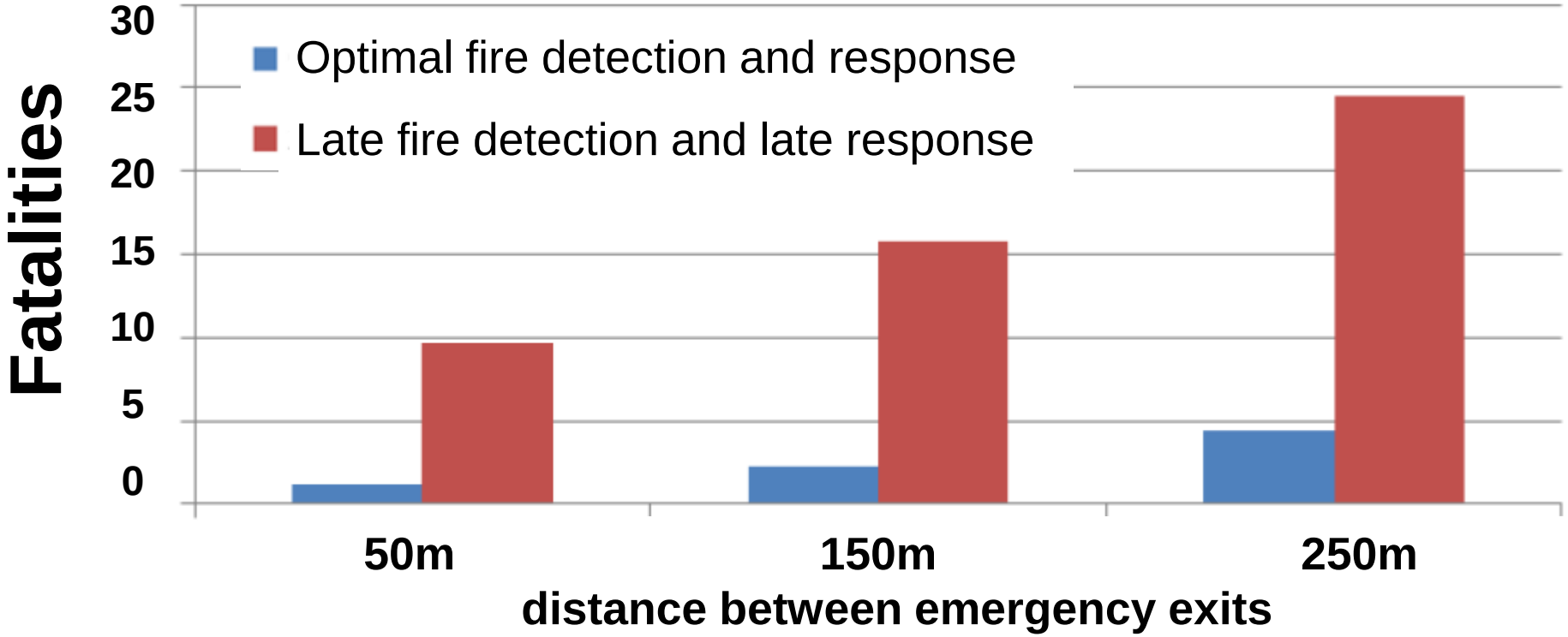
Step 4: Exit tunnel

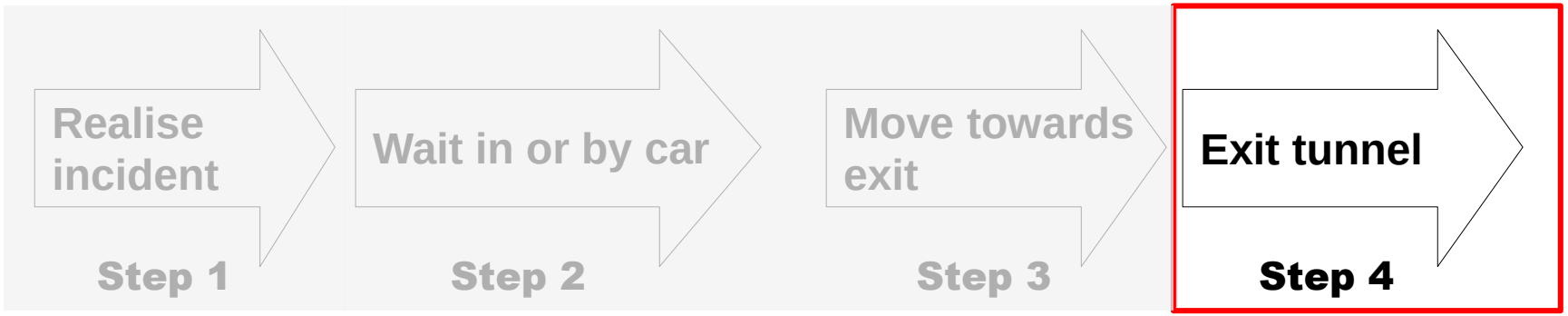
- Emergency egress are used, if the user have had positive experiences using emergency exits



Emergency exits

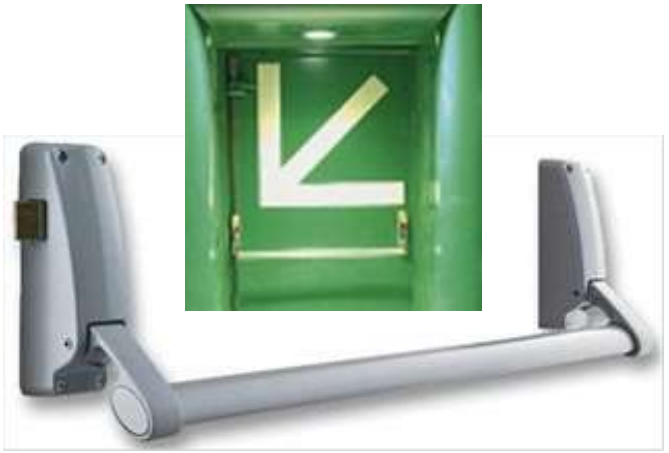
In case of ideal human behaviour a very efficient safety measure

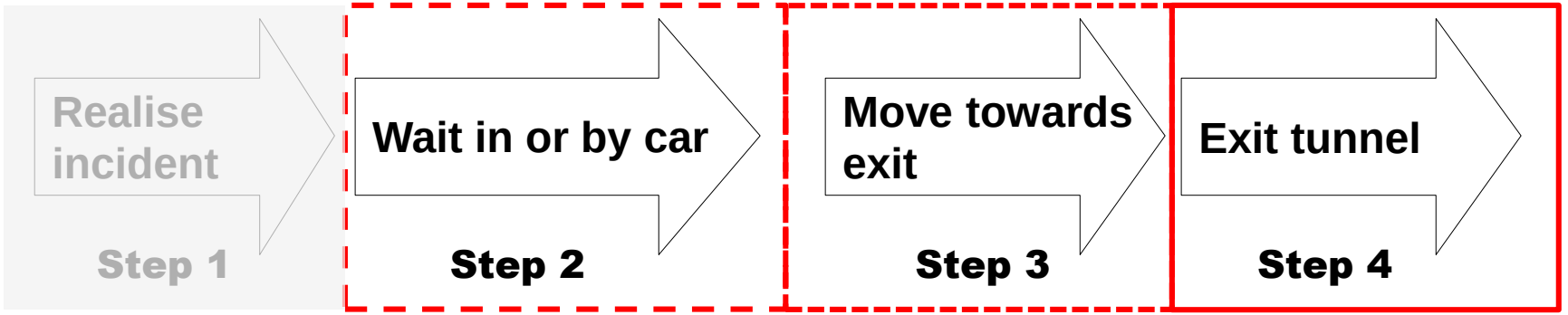




Egrees doors

Visible egress doors (green with light around, easy so use (e.g. opening force > 100 N) also from a wheelchair





Future technology

- Mobile phones
  - » Detection
  - » Information about congestion and traffic movements
  - » Contact to users
- Alarm via eCall
- ITS, car to car and/or infrastructure communication
- IR Camera, radar detection
- **Automated and autonomous cars**

- **… and everything has to function as envisaged i.e. the minimal operation conditions need to be known**

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- ***Thank you – questions ?***