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Optimising Fire Evacuation Procedures of the Dartford Tunnel: A Hybrid Simulation Approach

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INTRODUCTION

The Dartford Tunnels provide one of the most important links between the two sides of the River Thames in Southeast England. According to statistics from the Kent Country Council in 2012, the average daily traffic in the Dartford Crossing is more than 135,000 vehicles. Under this high traffic volume, a fire in the Dartford Tunnels can bring enormous damage to the economy of Southeast England, including possible injuries or even fatalities. A set of fire evacuation procedures are currently used by the management team of the Dartford Tunnels; however, these procedures maybe outdated and not optimised. To prevent injuries and deaths in the case of a fire in the Dartford Tunnels, the fire evacuation procedures should be reviewed and optimised. The optimisation process should target zero deaths in any tunnel fire scenario while minimising the evacuation time. Experimentation and simulation are the most common methods by which to optimise an evacuation strategy. However, owing to the costs and disruption to the daily tunnel operation associated with an experiment, the simulation approach is more suitable.

METHODOLOGY

This research focuses on using a scenario-based simulation analysis to determine the most optimised fire evacuation procedures for the Dartford Tunnels. The ultimate objectives of the optimisation are:

- *Achieving zero deaths and injuries in any fire scenario.*
- *Minimising the total evacuation time of the motorists.*

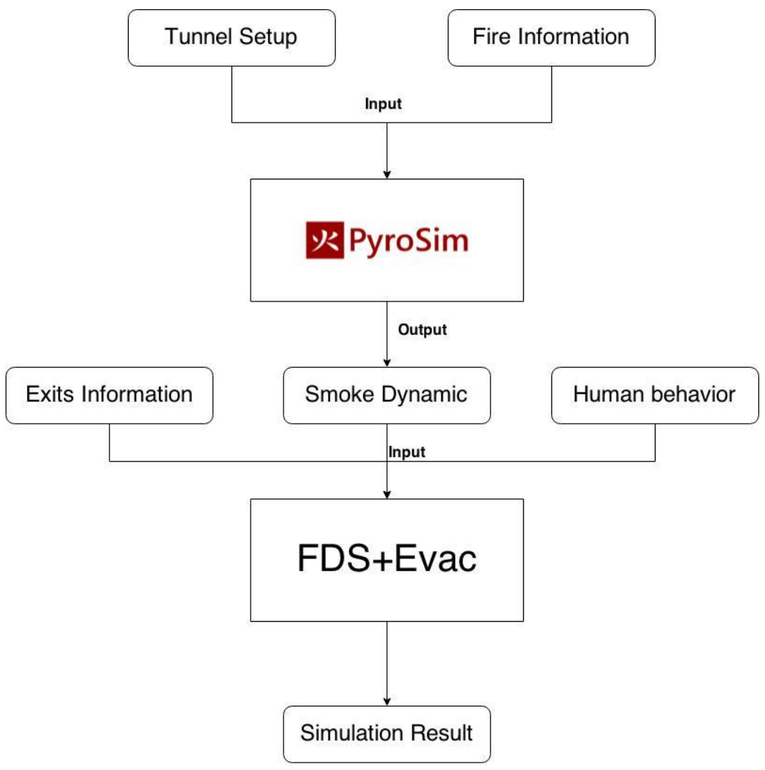
This can be fulfilled by a series of actions including the identification of factors that affect the evacuation, development of an optimisation strategy, and comparison of the simulation results.

SIMULATION MODELS

A series of scenario-based simulations are preformed with the hybrid use of two simulation models with PyroSim for smoke dynamics simulation and FDS+Evac for human evacuation simulation is extremely powerful. This is among the first attempts in the road tunnel fire safety field to use a hybrid simulation modelling technique to perform a scenario-based simulation analysis. (See figure 1)

The biggest strength of this technique is the ability to perform highly accurate detailed 3D CFD analysis to generate the smoke dynamic of a tunnel fire and use the output from PyroSim as an environment input of the evacuation modelling in FDS+Evac. Additionally, FDS+Evac also allows stochastic parameter inputs for human evacuation.

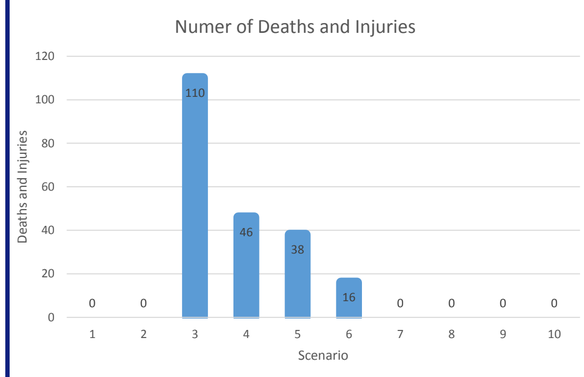
FIGURE 1



SCENARIOS

Simulation Number	Car Fire	Truck Fire	Exit Sign	Evacuation Alarm	Automatic Sprinklers	Mechanical Ventilation	More Exits
1	✓	×	×	×	×	×	×
2	✓	×	×	×	×	×	×
3	×	✓	×	×	×	×	×
4	×	✓	×	✓	×	×	×
5	×	✓	✓	✓	×	×	×
6	×	✓	✓	✓	✓	×	×
7	×	✓	✓	✓	×	✓	×
8	×	✓	✓	✓	✓(Linked)	✓	×
9	×	✓	✓	✓	✓(Independent)	✓	×
10.	×	✓	✓	✓	✓	✓	✓

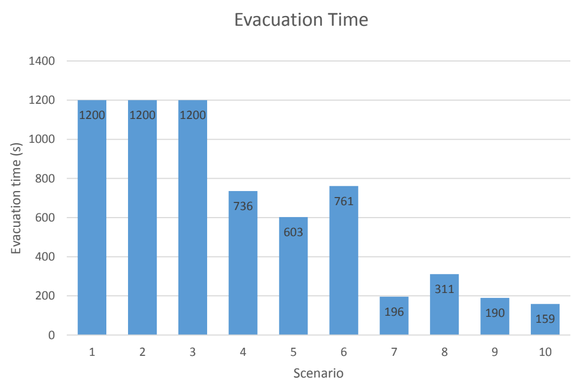
DEATHS AND INJURIES



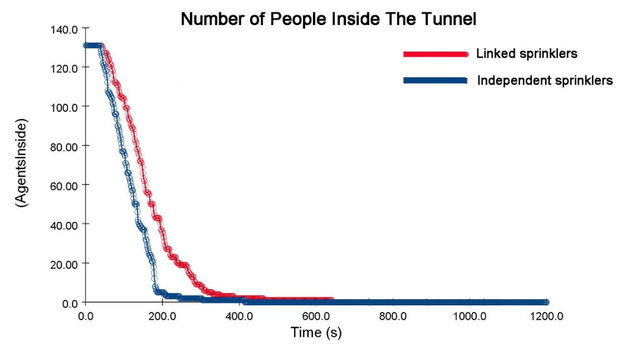
By comparing the deaths and injuries in each simulation scenarios, it can be seen that the mechanical ventilation is the ultimate solution to reduce the number of deaths to zero. (Scenario 7 – 10)

EVACUATION TIME

The results indicate that all measurements can reduce the evacuation time, except the automatic sprinkler system, which increases the escape time by creating wet condition. (Scenario 6 & 8)



INDEPENDENT SPRINKLER SYSTEM



Independent sprinkler system is proposed to encounter the wet condition problem caused by the traditional system. The simulation result states that the new system can reduce the evacuation time by 121s.

CONCLUSION

The mechanical ventilation is the ultimate solution to achieve zero deaths in a tunnel fire. All other procedures are important as well since they can reduce the evacuation time. The traditional sprinkler system should be replaced with the independent sprinkler system.

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