Computer simulation of VLTA evacuation performance: A report from the VERRES project

By

Prof. E.R. Galea, Dr. S.J.Blake and Dr. P.J.Lawrence

Fire Safety Engineering Group
University of Greenwich
http://fseg.gre.ac.uk
London
U.K.

Acknowledgements

- Professor E R Galea is indebted to the UK CAA for their financial support of his personal chair in Mathematical Modelling at the University of Greenwich.
- The authors are indebted to the EU DG TREN for the funding of this project (GMA2/2000/32039) under Framework 5
- **The views expressed in this paper are solely those of the authors.**

Contents

- Introduction
  - What is a VLTA?
  - Challenge posed by VLTA and BWB.
- The airEXODUS Evacuation Model
  - airEXODUS capabilities
  - Aircraft evacuation modelling and the need for data
  - Validation studies
- Applications to VLTA
  - stair case issues
- Applications to BWB
  - exit capacity issues
- Conclusions

What is a VLTA?

- **The A380 has been labelled a VLTA by some.**
- **Passenger Capacity:**
  - **A380**
    - **Three class: 550 passengers. Single class: 822 passengers**
  - **B747-400**
    - **Three class: 416 passengers. Single class: 660 passengers**
- **Configuration:**
  - **A380**
    - **Two decks, both full length, upper sill height 7.9m, single main stair linking decks.**
  - **B747-400**
    - **Two decks, partial upper deck, upper sill height 7.8m, single main stair linking decks.**
- **Normal (certification) Evacuation Procedure:**
  - **A380**
    - **Both decks evacuate independently of each other.**
  - **B747-400**
    - **Both decks evacuate independently of each other.**

What is a VLTA?

- **While it may be debated whether the A380 should be classified as a VLTA, the number of passengers that are seated on the upper deck make the A380 different to existing aircraft.**

- **Thus some of the issues associated with current large aircraft are magnified.**

- **However, many of the questions that arise for the A380 apply equally to existing large double deck aircraft.**

VLTA Evacuation Issues

- **VLTA pose considerable challenges to designers, operators and certification authorities.**
- **Questions concerning:**
  - **seating arrangement,**
  - **nature and design of recreational space,**
  - **the number, location and type of exits,**
  - **slide arrangement and possible congestion on the ground**
  - **the number of cabin crew required,**
  - **the nature of the cabin crew emergency procedures,**
  - **crew communication between decks.**

\- **These are some of the the "easier" questions!**

Introduction: More Difficult Questions

- Should passengers be allowed to travel between decks before exiting the aircraft?
- What implications does this have for crew evacuation procedures?
- What implications does this have for staircase design and location – e.g. number of staircases, number of lanes, location, riser height, location of hand rails, angle of orientation?
- How will crew communicate effectively to control such an evacuation on each deck and between decks?
- Will the proximity of multiple emergency slides have a detrimental effect on evacuation efficiency and safety?
- Can exits be safely spaced further apart than the current arbitrary 60 foot limit?
- What impact will all these issues have on evacuation times and survivability?

Introduction: Yet More Questions

- **In order to efficiently complete an evacuation, will it be necessary to extend emergency procedures to the marshalling of those passengers evacuated to the ground?**
- **Consider an evacuation scenario with 800 passengers on the ground, possibly on one side of the aircraft.**
  - **What impact will they have on fire fighting and rescue operations?**
  - **Who should take responsibility for marshalling the grounded passengers?**

airEXODUS application to VLTA staircase issues

- As part of the EU funded project VERRES, airEXODUS used to examine issues associated with staircase design, location and associated crew procedures.
- Hypothetical VLTA aircraft designed called the ***UOGXXX***
- Examine issues associated with design and use of internal staircase for evacuation.

Evacuation scenarios considered

- Total scenarios investigated include:
  - **Scenario 1: All exits on BOTH decks**
  - **Scenario 2: 90-second exit configuration**
  - **Scenario 3a: ONLY lower deck exits**
  - **Scenario 3b: Crew rotate passengers**
  - **Scenario 3c: Crew redirect passengers**
  - **Scenario 3d: Scenarios involving stair width**
  - **Scenario 3e: Scenarios involving stair location**
  - Scenario 4: Passengers moving between decks
  - Scenario 5: Two staircases.
- Only results for scenarios in blue are presented here.
- Full report available on our web site at:

  http://fseg.gre.ac.uk/fire/VERRES_Project.html

Behaviour implemented

- While airEXODUS has the ability to represent “extreme” passenger behaviour of the type reported in actual aviation accidents, such as seat jumping, this type of behaviour is not included in these simulations. All the cases considered here are run under certification type evacuation conditions involving:

(i) Assertive cabin crew located at each Type-A exit,

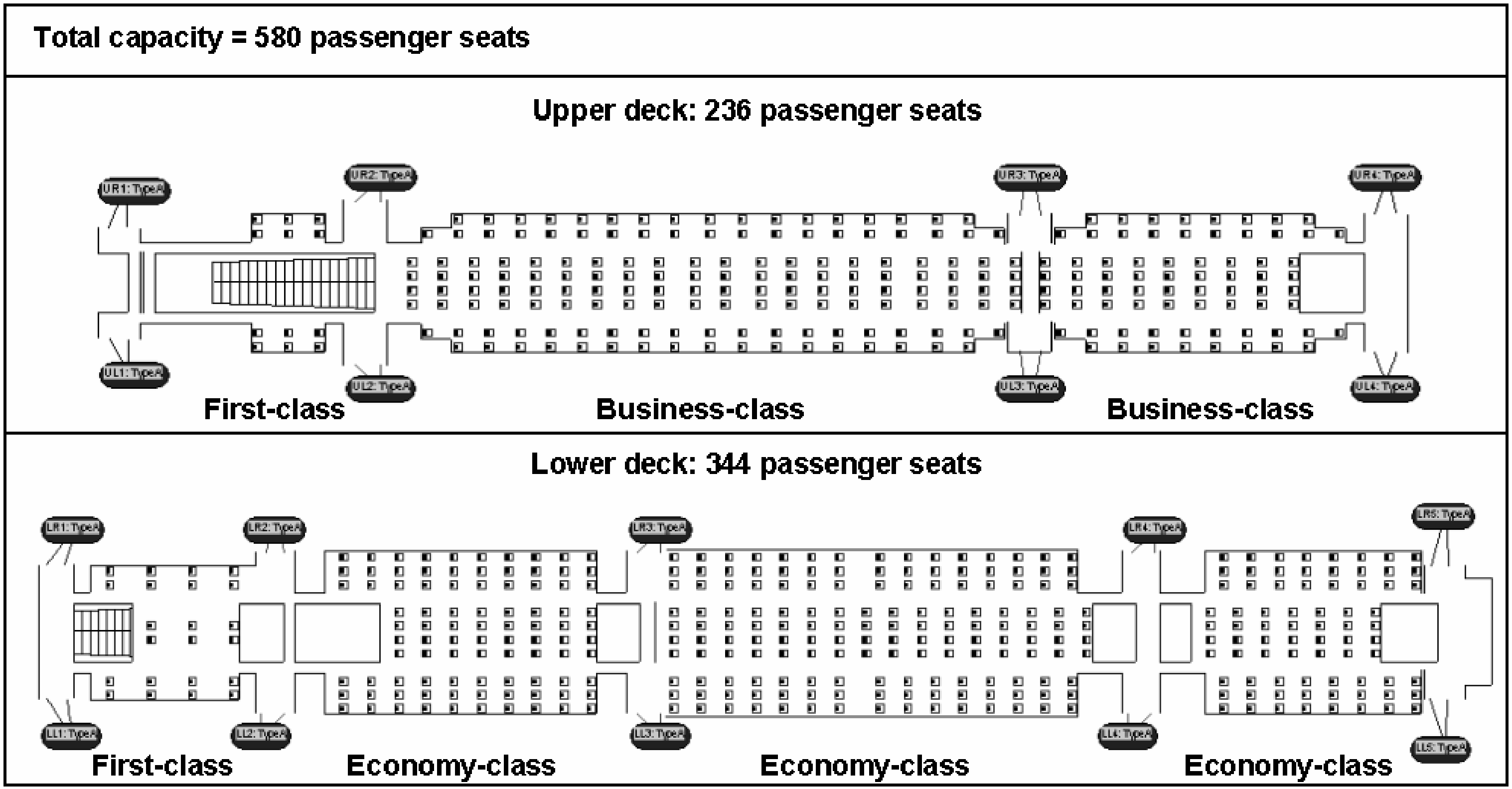
(ii) Orderly passenger behaviour of the type found in certification evacuations,

(iii) Each exit being made ready in a representative time derived from past relevant certification tests.

(iv) UD exits assume pax exit hesitation times derived from certification tests for B747 UD exits.

(v) All times quoted are out of aircraft times not on ground times

UOGXXX layout



VLTA test aircraft configuration

- 580 passengers in three classes
  - 236 upper deck passengers
  - 344 lower deck passengers
- 9 exit pairs
  - 4 upper deck Type-A exits
  - 5 lower deck Type-A exits
- ***UOGXXX has a single staircase located in the front of the aircraft which is two lanes wide.***

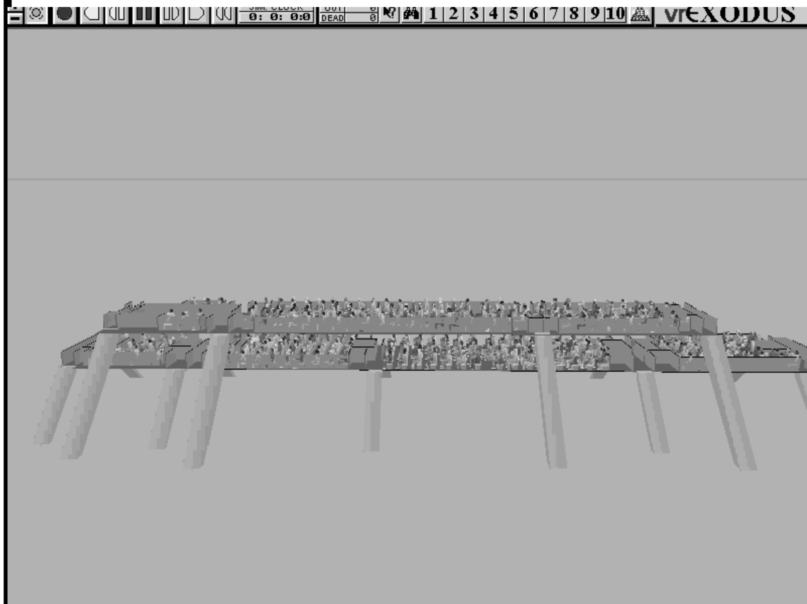
Scenario 2 description

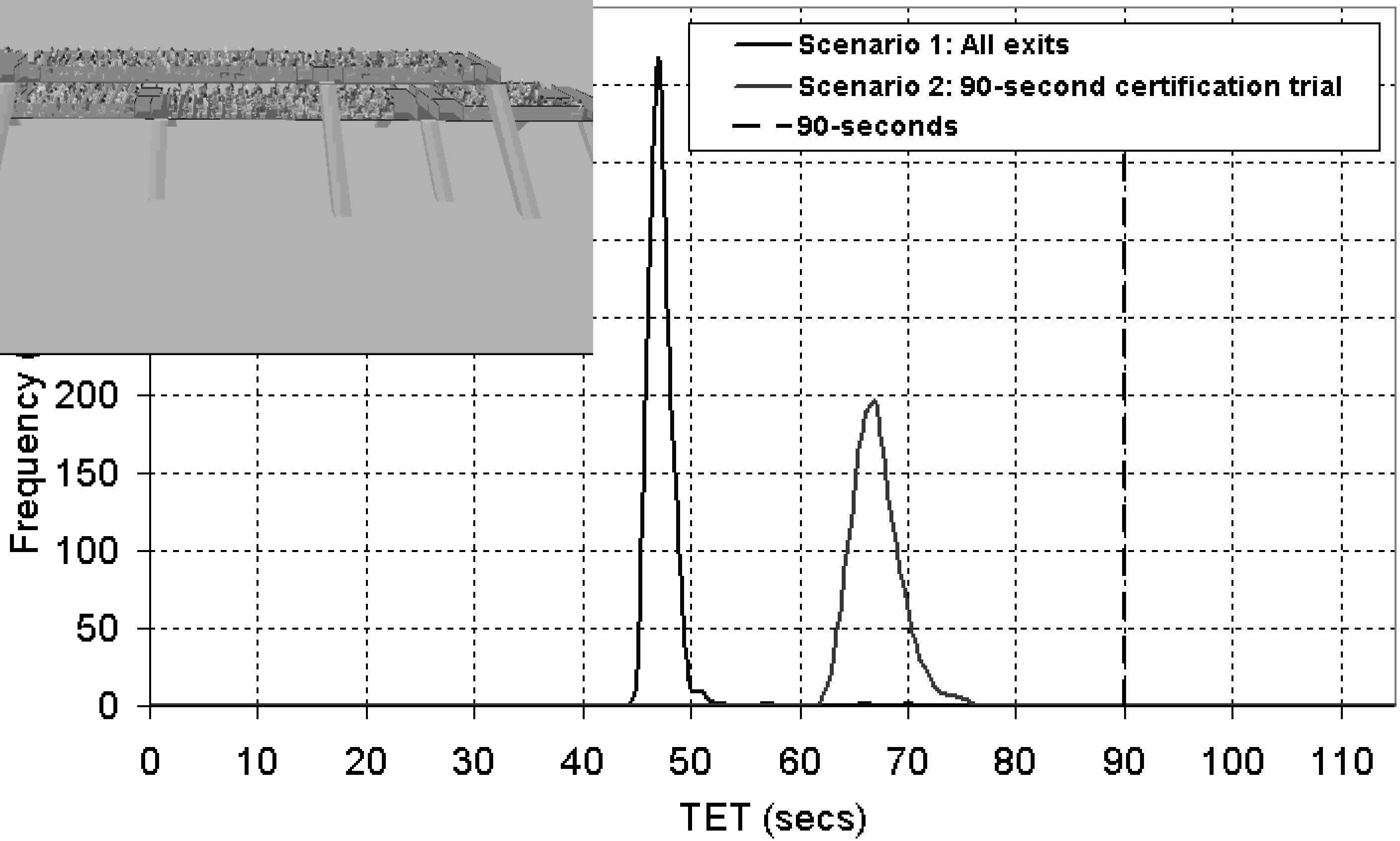
- ***Scenario 2:***
  - *Typical 90 second scenario*
  - *Half upper and lower deck exits i.e. 9 Type-A exits available for evacuation*
  - *All 236 upper deck passengers make use of 4 Type-A exits on upper deck*
  - *All 344 lower deck passengers make use of 5 Type-A exits on lower deck*
  - ***No passenger movement between decks.***

Scenario 2: results

- Average evacuation time of **66.6** seconds
- All simulations are under 90-seconds
- Passengers waste, on average, 57% of their time in congestion
- Upper deck finishes, on average, **2** seconds earlier than lower deck
- Exit flow rates were comparable to those of 90-second certification trials i.e. exits working with good efficiency.

Scenario 2: results





Scenario 3(a) description

- ***Scenario 3(a):***
  - *All passengers are forced to use lower deck exits*
  - *All exits on lower deck available i.e. 10 Type-A exits*
  - *All 236 upper deck passengers must use the stairs*
  - *In total 580 passengers make use of the 10 lower deck Type-A exits.*

Scenario 3(a): results

- Average evacuation time of **149** seconds
- Passengers travel longer distances on average, 13.9m compared with 8.4m.
- After approximately 45 seconds ONLY upper deck passengers are left.
- All upper deck passengers make use of only the R1 and L1 exits.
- Could evacuation time be improved if upper deck passengers were redirected in order to utilise the idle R2 and L2 exits?

Scenario 3(a): results

- Problem can be viewed using the notion of a balanced evacuation system:

Discharge (capacity) ˜ Stair (capacity) ˜ Supply (capacity)

- By using redirection at the base of the stairs we would increase the **Discharge Capacity**, as passengers would have access to four exits instead of two

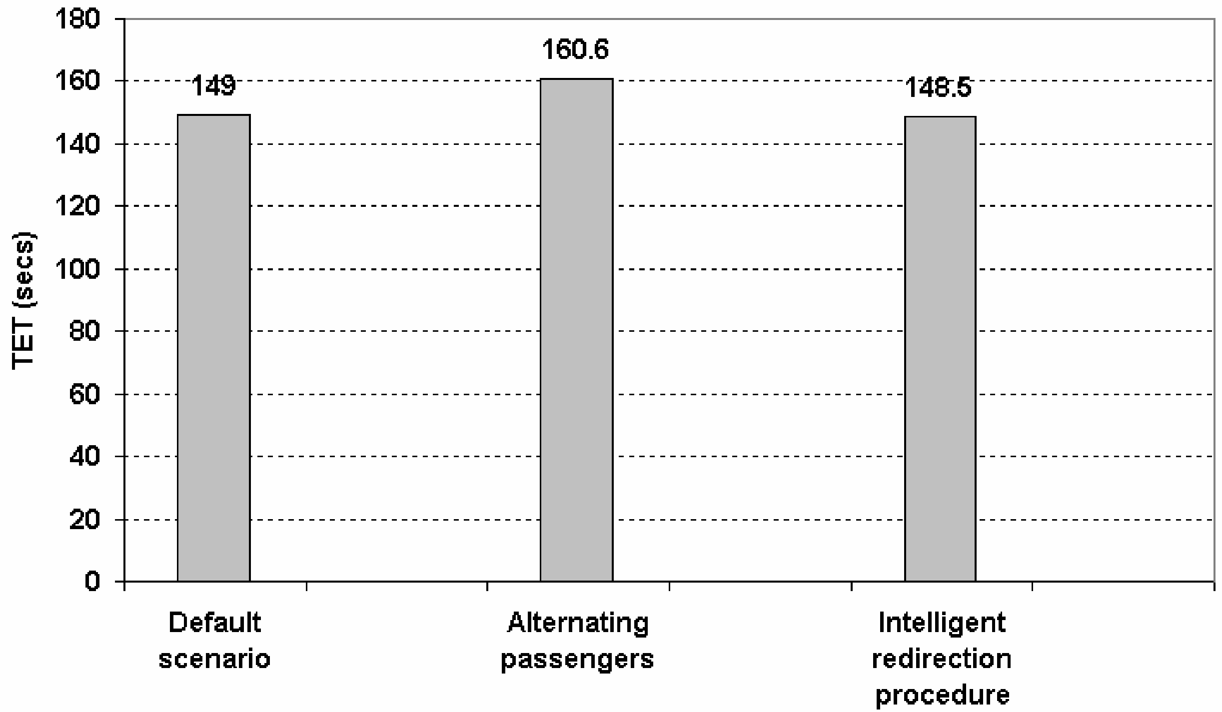
Scenario 3(b,c) description

- ***Scenario 3(b,c):***
  - *As scenario 3a but with crew centred redirection at the base of the stairs.*
  - *Passengers redirected to make use of front 4 exits.*
  - *Two strategies tested.*
  - *Scenario 3b examines passengers being alternatively directed to the L1 and L2 or R1 and R2 exits.*
  - *Scenario 3c examines ideal passenger redirection between L1 and L2 or R1 and R2 exits. Assumes crew have perfect knowledge of cabin situation ⇒* ***represents ideal situation.***

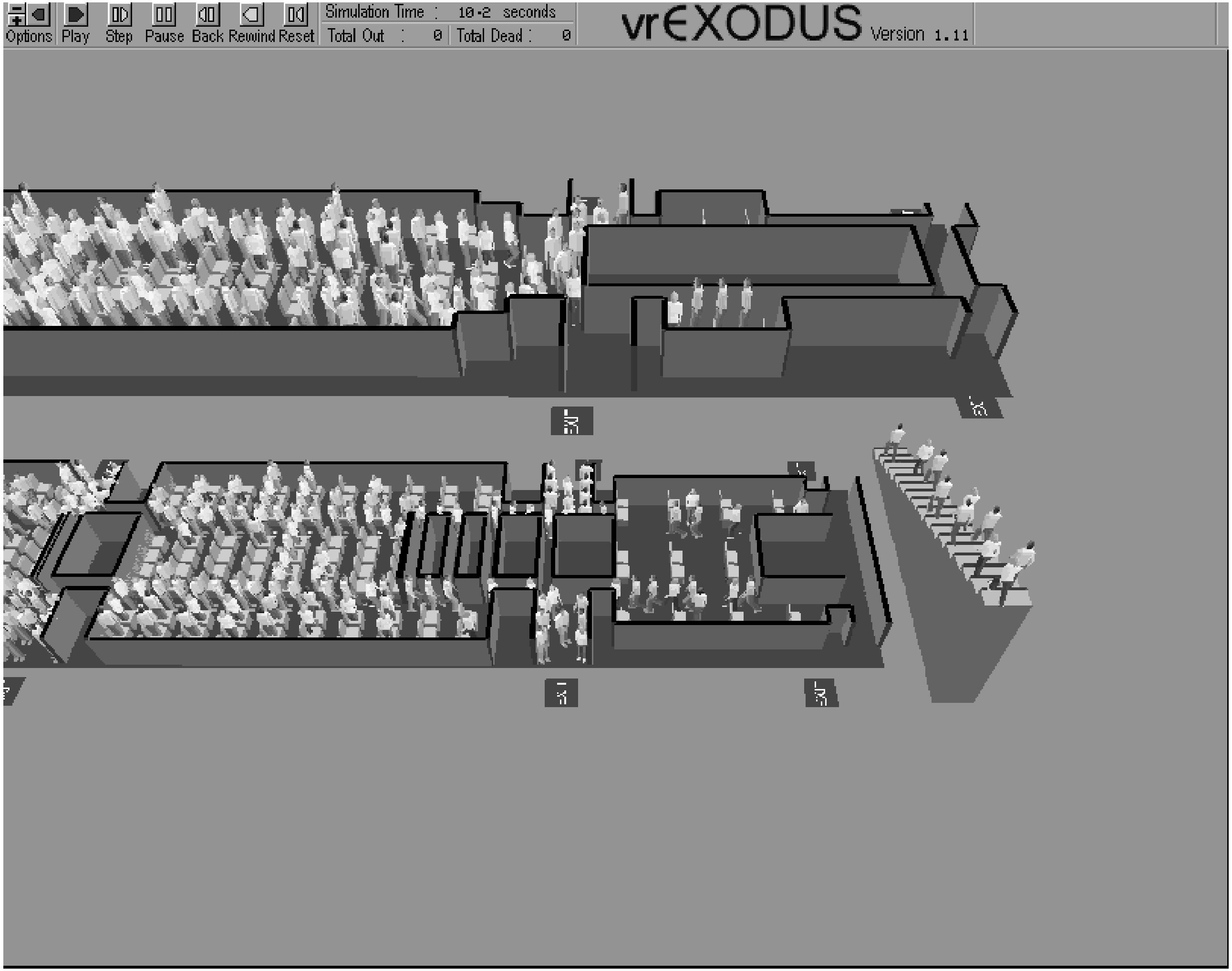
Scenario 3(b,c): results

-Alternating passengers worsens evacuation

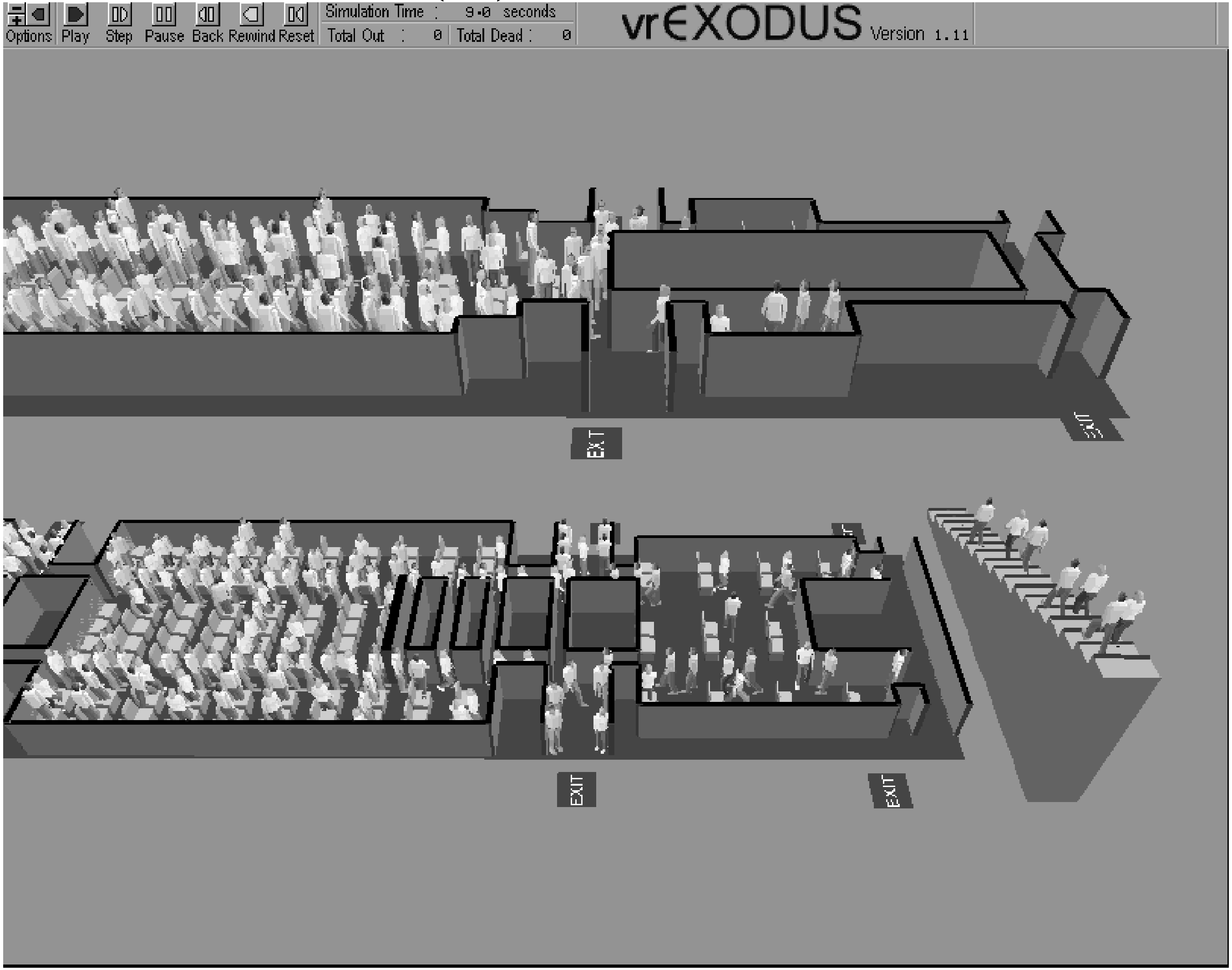
-Ideal redirection makes no difference



Scenario 3(b): alternate redirection



Scenario 3(c): Ideal redirection



Scenario 3(b,c): results

- Why is the situation not improved??
- Exit flow rates achieved by the L1 and R1 exits in Scenario 3a were less than should be expected for Type-A exits.
- Thus bottleneck not caused by exit capacity and so redirection should not be expected to provide any improvement – as demonstrated!
- Bottleneck must be either the stair capacity or the supply of passengers to the stairs.
- This is demonstrated in other scenarios.

Scenario 3(b,c): results

- The **Supply (capacity)** cannot be the source of the bottleneck as congestion exists at the top of the stairs (as seen in video)
- Thus, the solution could be to expand the stair width to balance the evacuation system

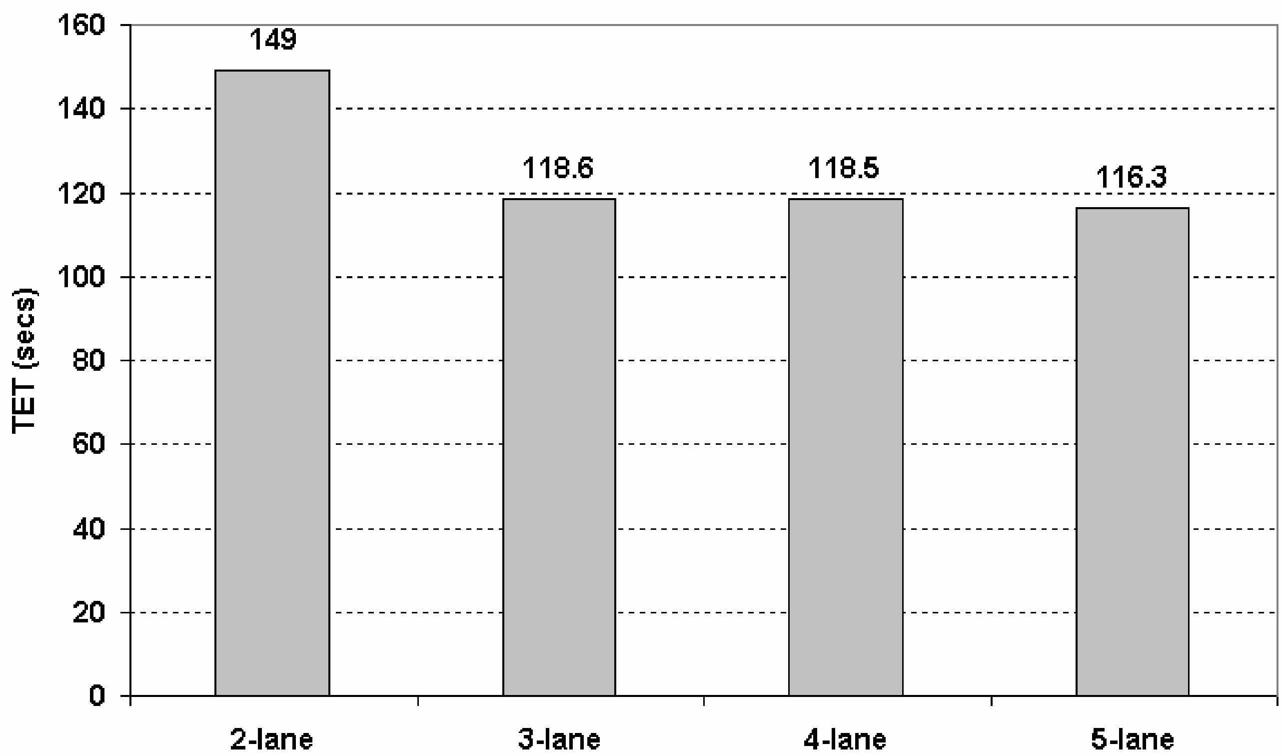
Discharge (capacity) ˜ Stair (capacity) ˜ Supply (capacity)

Scenario 3(d) description

- ***Scenario 3(d):***
  - *As scenario 3a but with wider staircase.*
  - Widths considered:
    - 2-lanes (current configuration)
    - 3-lanes
    - 4-lanes
    - 5-lanes
  - With/without crew redirection at base of stairs

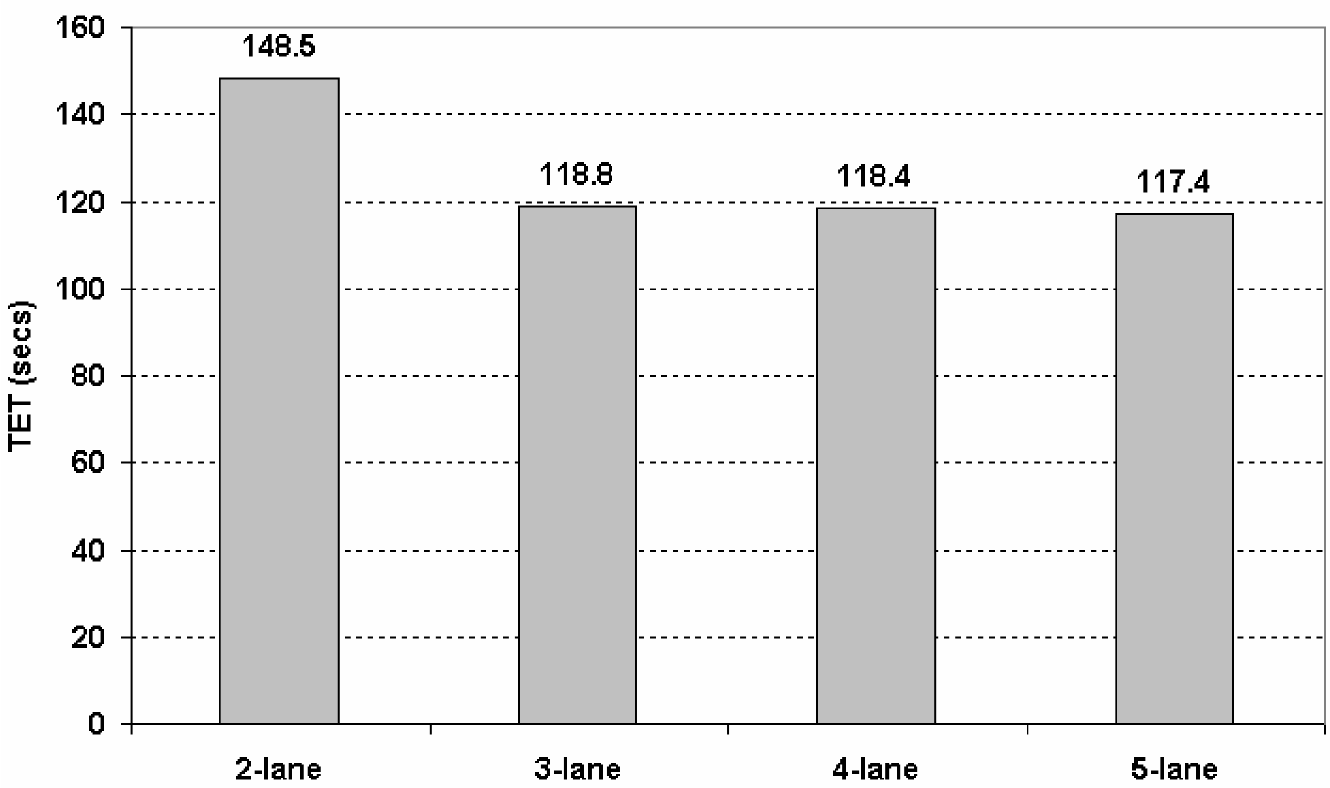
Scenario 3(d): results

- Initial decrease, but TET forms a plateau.
- No improvement above 3 lanes can be achieved.



Scenario 3(d): results

- No advantage is gained through the inclusion of crew redirection at the base of the stairs



Scenario 3(d): results

- Why does the TET form a plateau??
- Two possible reasons

A) At increased stair widths, the discharge capacity is insufficient to meet the demands of the increased stair widths

Discharge (capacity) < Stair (capacity) ˜ Supply (capacity)

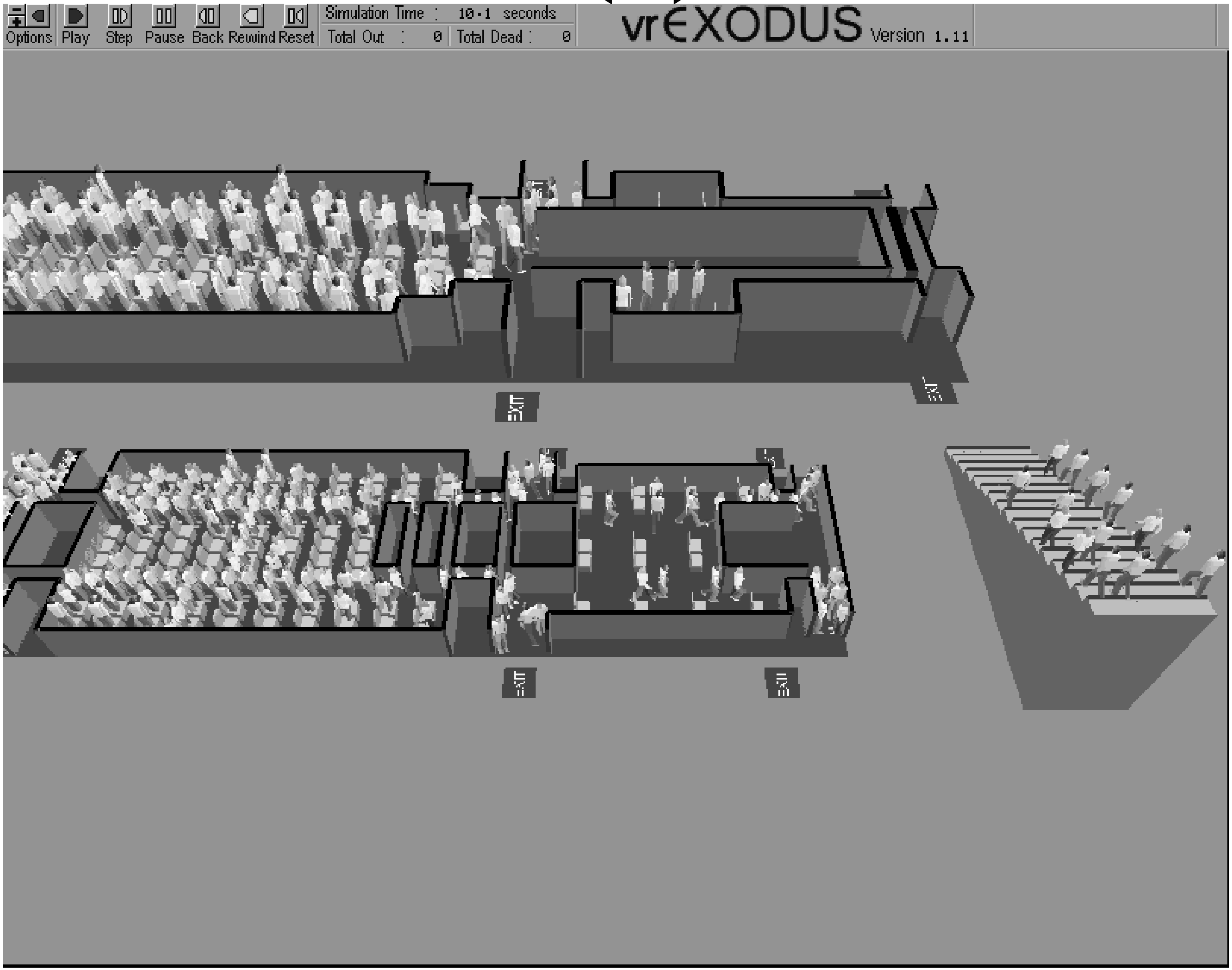
OR

B) The supply to the stairs is insufficient for their capacity

Discharge (capacity) ˜ Stair (capacity) > Supply (capacity)

- We can eliminate A) as increasing the **Discharge (capacity)** through redirection had little effect AND the R1 and L1 flow rates were quite low (approximately 65 passengers/minute)

Scenario 3(d): results

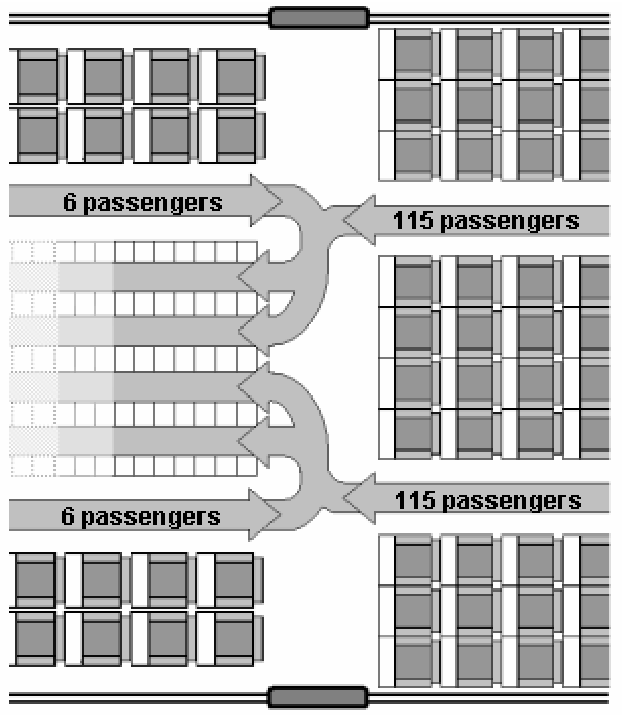


Scenario 3(e) description

- ***Scenario 3(e):***
  - *As scenario 3d but with relocated stair position.*
  - Widths considered:
    - 2-lanes (current configuration)
    - 3-lanes
    - 4-lanes
    - 5-lanes
  - With/without crew redirection at base of stairs

Scenario 3(e): results

- In the original design passenger flow into the stairs is essentially from one direction and from only two aisles.



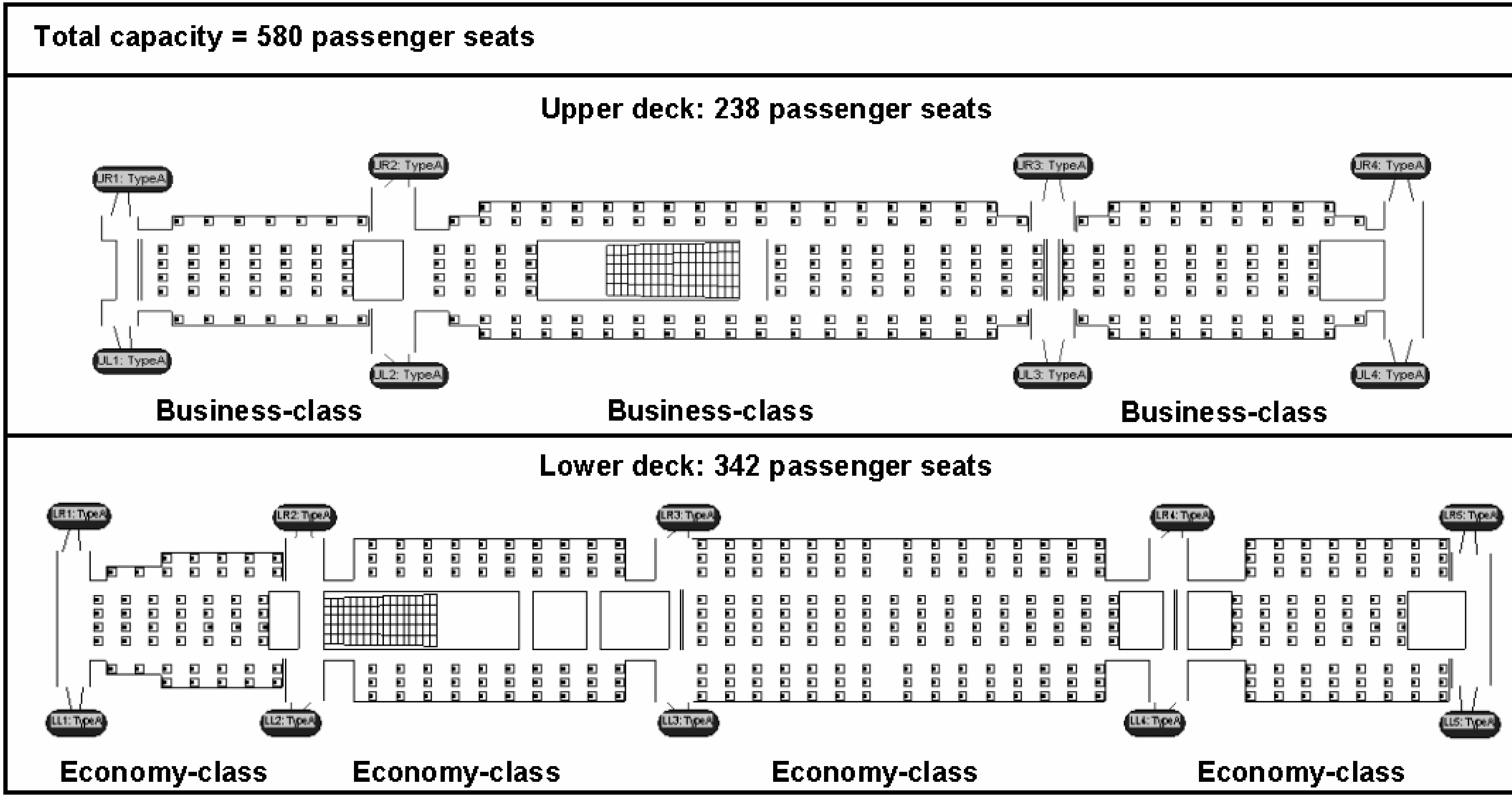
-Typical flow rate for a passenger aisle under certification conditions is approximately 74 paxs/min

-Thus, the two aisles only generate a supply flow rate of approximately 144 paxs/min.

-Typical stair can achieve ***40 pax/min/unit width, thus with 4 lanes, require a feed rate of 160 paxs/min to satisfy stairs.***

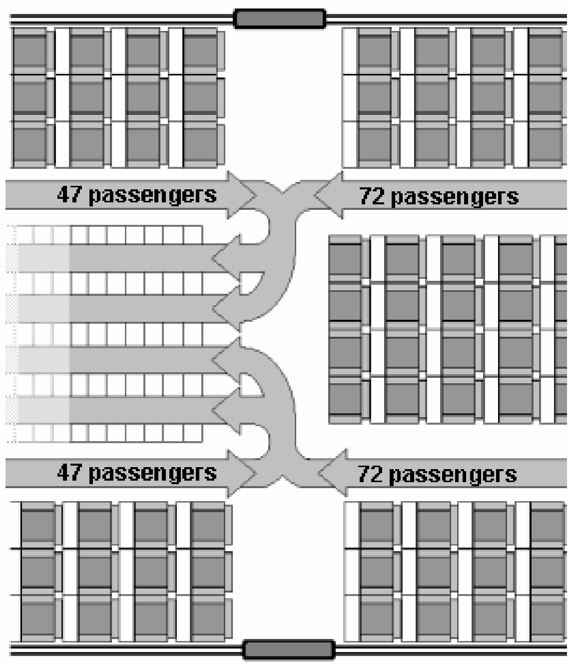
Scenario 3(e): results

- We have implemented a geometry change with CENTRALLY located stairs



Scenario 3(e): results

- This is a better design as it generates four flows into the stairs.

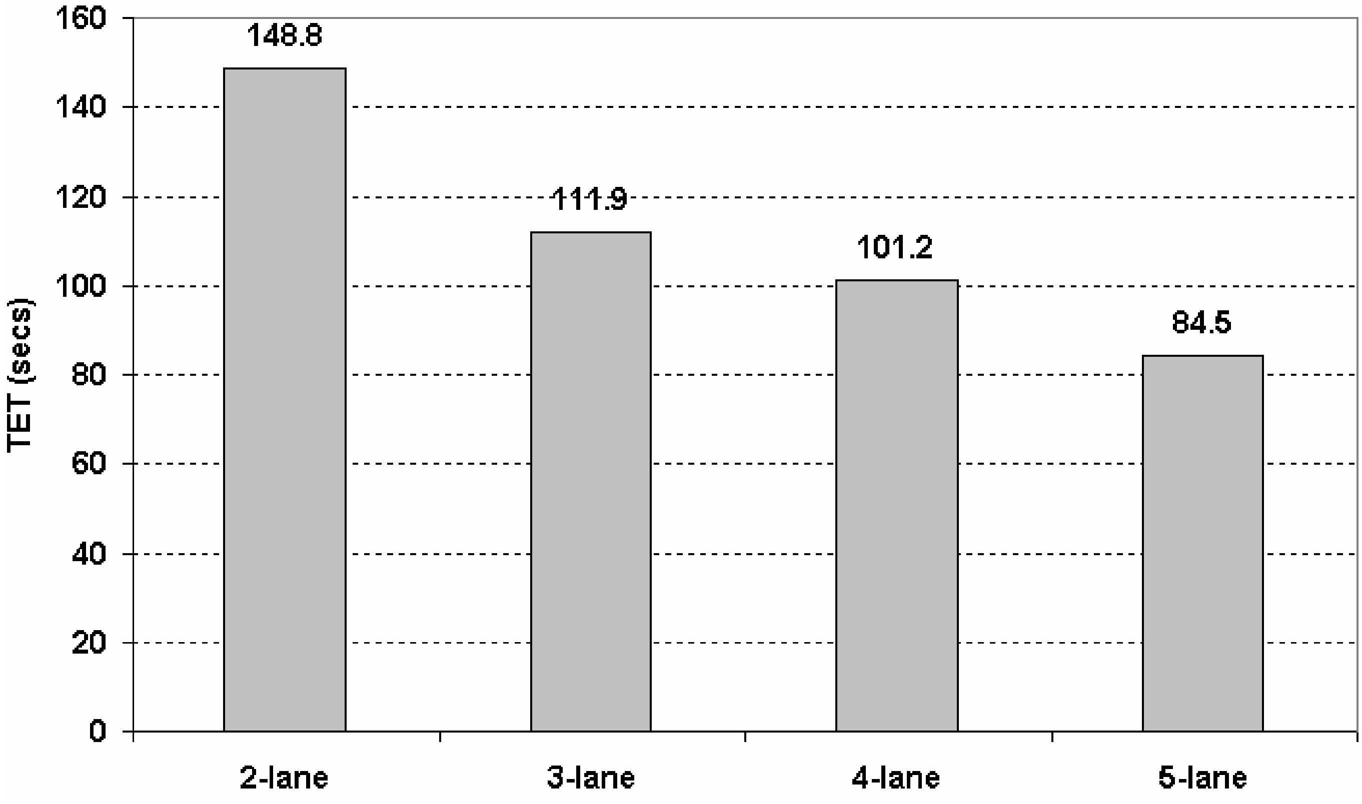


-Given an approximate aisle flow rate of 74 paxs/min,

-Simplistically we could expect the supply to the stairs to be increased to approximately 296 paxs/minute, at least partially through the evacuation.

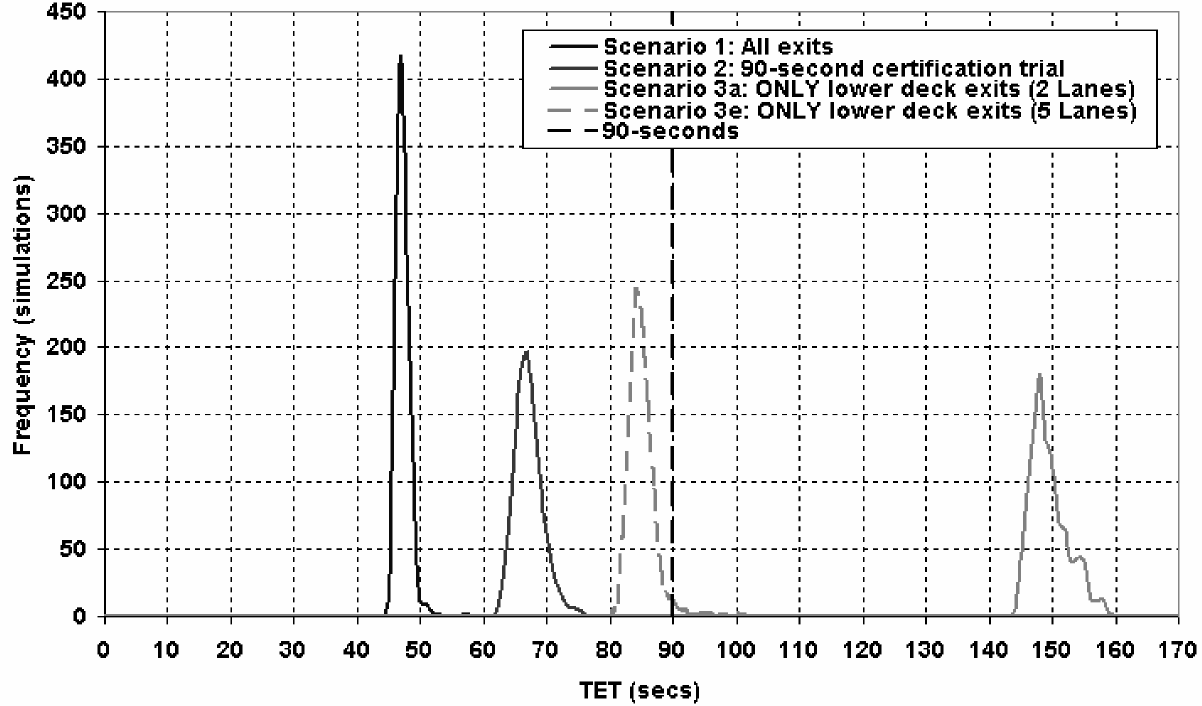
Scenario 3(e): results

- Model predictions show that with the centrally located stairs we get a continuous decrease in TET as the stair width is increased



Scenario Comparison

- Results for Scenarios 1, 2, 3a and 3e.



•If crew are placed at base of stairs and redirect paxs, then ALL cases with 5 lines are sub 90 seconds.

Concluding Comments

• Evacuation between decks using the main stairs is possible and in some cases may even be preferable to using the upper deck slides.

• To cater for these situations it is essential to have a good understanding of how evacuation efficiency is influenced by:

- the layout of the approach to the stairs,
- extent of possible catchment areas that may feed the stairs,
- the geometry of the base of the stairs (amount of available space),
- the relative location of the stair base to exits,
- role of crew at the base of the stairs and at the head of the stairs.

•This presentation has demonstrated how aircraft evacuation models can be used to explore these issues.

FSEG

Concluding Comments

- Areas that require further fundamental research include :
  - Collection of pax exit hesitation time data at high sill height exits.
  - Performance of paxs on stairs in these type of aircraft.
  - Impact of stair geometry on evacuation efficiency.
  - Preference for upper deck paxs to utilise stairs in emergency situations.