Computer Simulations on Egress Assistant Devices During Aircraft Emergency Evacuation

Ching-Jui Chang, Hae Chang Gea

Rutgers, The State University of New Jersey

Mechanical and Aerospace Engineering

Program Manager: Dr. Mac McLean, FAA, CAMI

Motivation

- Full scale test is…
  - costly
  - dangerous
  - time consuming
  - inconsistent
- Computer simulation provides…
  - information on many what-if scenarios
  - abilities to incorporate various hazardous conditions
  - better understanding of what can happen
  - test of effects on new devices

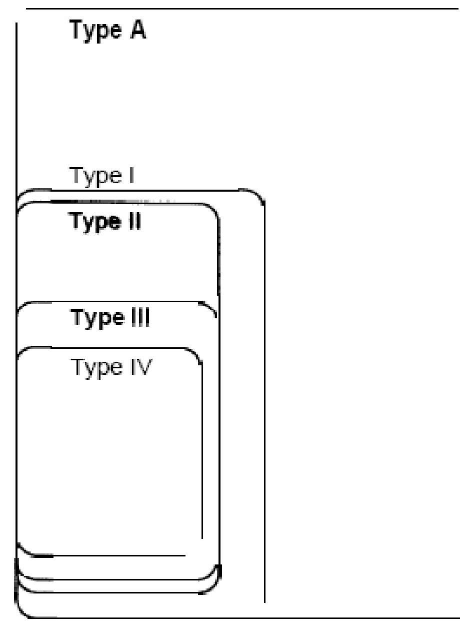
Computer Simulation Modeling

- Various vehicle structures such as exits, aisles, seats, lavatories, galleys, etc. to provide a near-real environment for occupants to move and escape.
- Human-structure interactions may affect the evacuation process. They are modeled in this study.
- Egress Assistant Devices can restore the evacuation efficiency for a given egress. The effect of the devices are evaluated.

Vehicle Structure Modeling (Exits)

Box I-A--Description of Passenger Emergency Exits

Type A[a]	Rectangular opening at least 42 inches wide by 72 inches high, with specified dimensions for passageways to main and cross aisles. Floor-level Type A exits must be equipped with dual-lane emergency slide. Overwing Type A exits with step-downs[b] outside the airplane typically have automatically deployed and erected means of reaching the wing and ground.
Type I[a]	Floor level exit at least 24 inches wide by 48 inches high.
Type II	Floor level exit at least 20 inches wide and 44 inches high. May also be located over the wing, with step-up inside the airplane of no more than 10 inches and step-down outside the airplane not exceeding 27 inches.
Type III[a]	Rectangular opening at least 20 by 36 inches with step-up not to exceed 20 inches. Most often placed over the wing, having stepdown not exceeding 36 inches.
Type IV[c]	Over-the-wing exit no less than 19 by 36 inches, with step-up of no more than 29 inches and step-down no greater than 36 inches.
Tail[a]	Similar to the Type I exit in size, a *ventral* exit is a passage from the passenger compartment through the plane's fuselage down a set of stairs to the ground. Tail *cone* exits lead directly out of the airplane's tail onto an escape slide.



[a]Exit types most commonly used in large transport aircraft.
[b]*Step-down* is the actual distance between the bottom of the required opening and a usable foothold, extending out from the fuselage, that is large enough to be effective without searching by sight or feel. *Step-up* is the height from the floor of the cabin to the lower sill of the exit.
[c]Used in aircraft having fewer than 10 passenger seats.

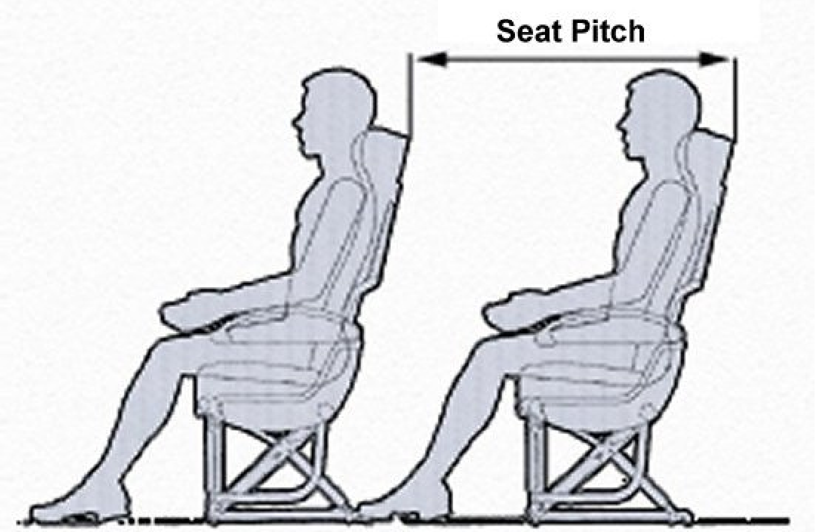
SOURCE: Office of Technology Assessment, 1993, based on 14 CFR 25.807; Daniel A. Johnson, *Just in Case: A Passenger's Guide to Airplane Safety and Survival*, (New York, NY: Plenum Press, 1984), p. 148; and Mary Edwards and Elwyn Edwards, *The Aircraft Cabin: Managing the Human Factors* (Hants, England: Gover Technical Publishing Co., 1990), p. 140.

Vehicle Structure Modeling (Exits)

Door Type	Max # of Passengers		AREA		
	Max # per door	Ratio	Size(in)	Area(in^2)	Ratio
Type – A	110	100%	42×72	3024	100%
Type - B	75	68%	32×72	2304	76%
Type - C	55	50%	30×48	1440	48%
Type -	45	41%	24×48	1152	38%
Type -	40	36%	20×44	880	29%
Type -	35	31%	20×36	720	24%
Type -	9	8%	19×26	494	16%

Vehicle Structure Modeling (Aisles)

- Space between rows of seats is much less than regular aisle.
- Moving along a row is very slow
- The moving speed depends on location



http://www.aerospaceweb.org

Vehicle Structure Modeling (Aisles)

- First Class, Business Class and Economy Class seats provide different size of spaces and occupant densities. These effects are built into our computer simulations.

Passenger Reaction Modeling

- Assumptions on passengers
  - Are not fully aware of the status of the vehicle,
  - Tend to stay in a decided direction unless other direction shows a significant advantage,
  - Are free to make their own decision on which door to go to and may change target door at any time based on the evacuation condition.
- Passengers' Strategy
  - Find a nearest door to go to and observe how the current moving line is moving,
  - Switch to other exits when time to evacuate could be significantly less.

Civilian Aviation Regulation

- Evacuation Requirements: 90 Seconds

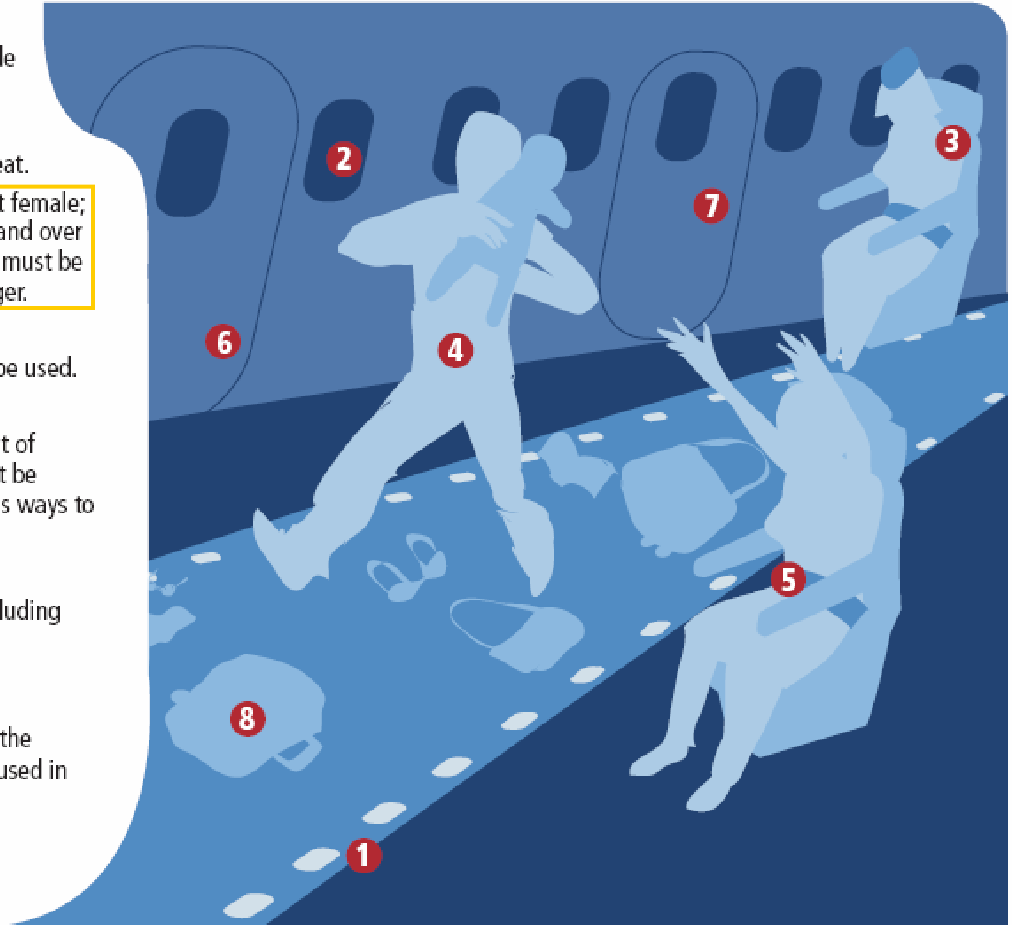
FAA REQUIREMENTS FOR EVACUATION DRILL

1. Only the plane's internal emergency lighting system can provide illumination.
2. Exterior light level can be no greater than 0.3 foot-candle.
3. Each crew member must be seated in the normally assigned seat.
4. Passenger load must be representative with at least 40 percent female; 35 percent over 50 years old; at least 15 percent must be female and over age 50. Three life-size dolls (not included in total passenger load) must be carried by passengers to simulate live infants 2 years old or younger.
5. Passengers must have seat belts on when drill starts.
6. Passengers can't know the location of the emergency exits to be used.
7. Only half of the emergency slides/doors can be used.
8. Before start of drill, about one half of the total average amount of carry-on baggage, blankets, pillows and other similar articles must be distributed at several locations in aisles and emergency exit access ways to create minor obstructions.
9. No practice runs are allowed before the drill.
10. Evacuation test is over when the last person on the plane, including crew members, is on the ground.

DECEMBER CHANGES TO FAA REQUIREMENTS

1. Slides can be deployed before the drill begins, but doors inside the plane must be covered so passengers do not know which will be used in the drill.
2. Low-level light can be used outside the plane during the test.

Source: FAA



Simulator Validation

- Validation
  - The computer simulation should be validated to ensure accurate representation of the real situations
  - Six previously performed evacuation drill are used to justify the model
  - Monte Carlo Simulation was performed on those cases for 10,000 iterations based on the configuration of the certification cases
- Passenger Distribution
  - Young male, old male and young female, old female

Speed Step	**Fastest**	**Moderate**	**Slow**
Ratio	60%	25%	15%

Validation Cases

BODY TYPE	CASE #	SEAT		DOOR		
		NUMBER	LAYOUT	TYPE	NUMBER (pairs)	OPEN DOOR POSITION
WIDE BODY	CASE 1 (83.7sec)	255	2-3-2	A	2	R1, R3
					1	L2
	CASE 2 (72.6sec)	**285**	2-3-2	A	2	R1, R4
					2	R2, R3
	CASE 3 (71.7sec)	351	2-4-2	A	2	R1, L4
					2	R2, L3
	CASE 4	440	3-4-3	A	4	L1,L2,L3,L4
NARROW BODY	CASE 5 (64.1sec)	159 (149)	3-3	C	2	R1, R3
					1	R2
	CASE 6 (78.5sec)	**188**	3-3	C	2	R1, R4
					2	R2, R3

Validation Case 1

- Wide Body Vehicle
- 255 Passengers
- Used 83.7 sec
- Opened doors: R1,L2,R3

1(A)

3(A)

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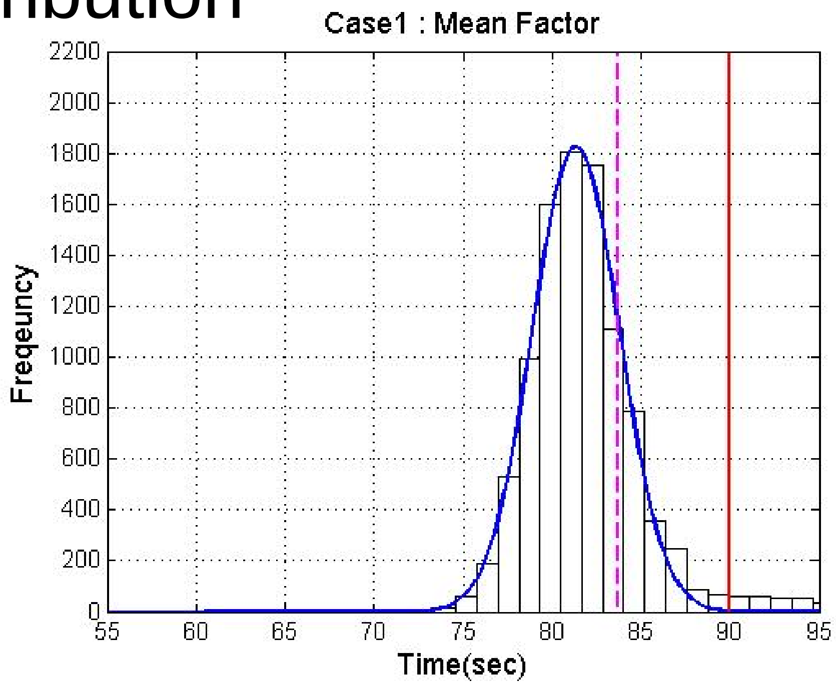
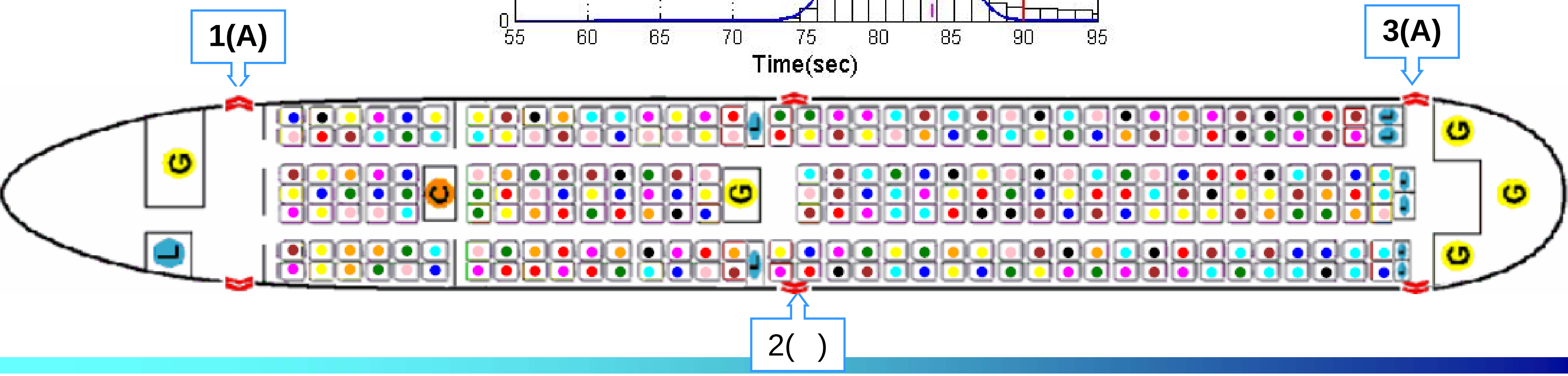
2( )

Validation Case 1

- Time distribution





Validation Case 2

- Wide Body Vehicle
- 285 Passengers
- Used 72.6 sec
- Opened doors: R1,R2,R3,R4

1(A)

2( ), 3( )

4(A)

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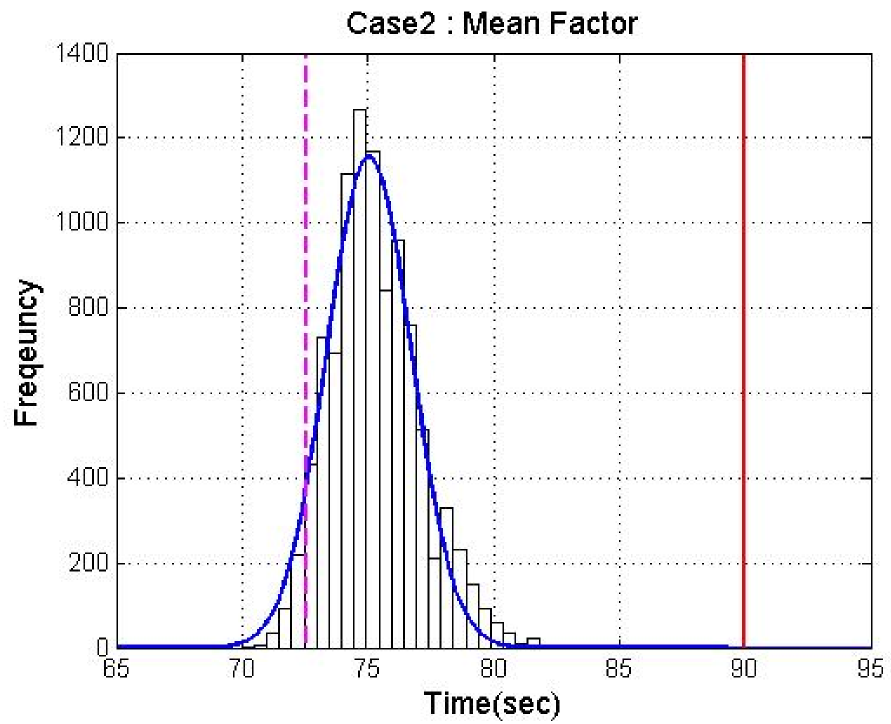
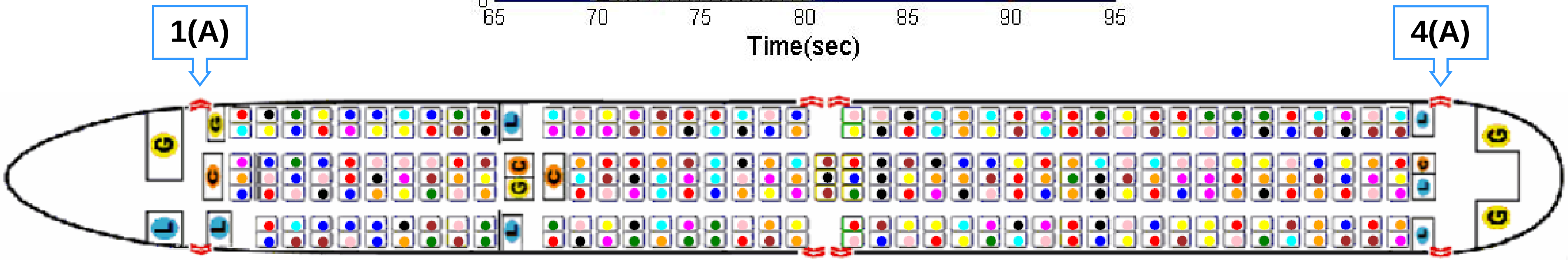
Validation Case 2

- Time Distribution





Validation Case 3

- Wide Body Vehicle
- 351 Passengers
- Used 71.7 sec
- Opened doors: R1,R2,L3,L4

1(A)

2(A)

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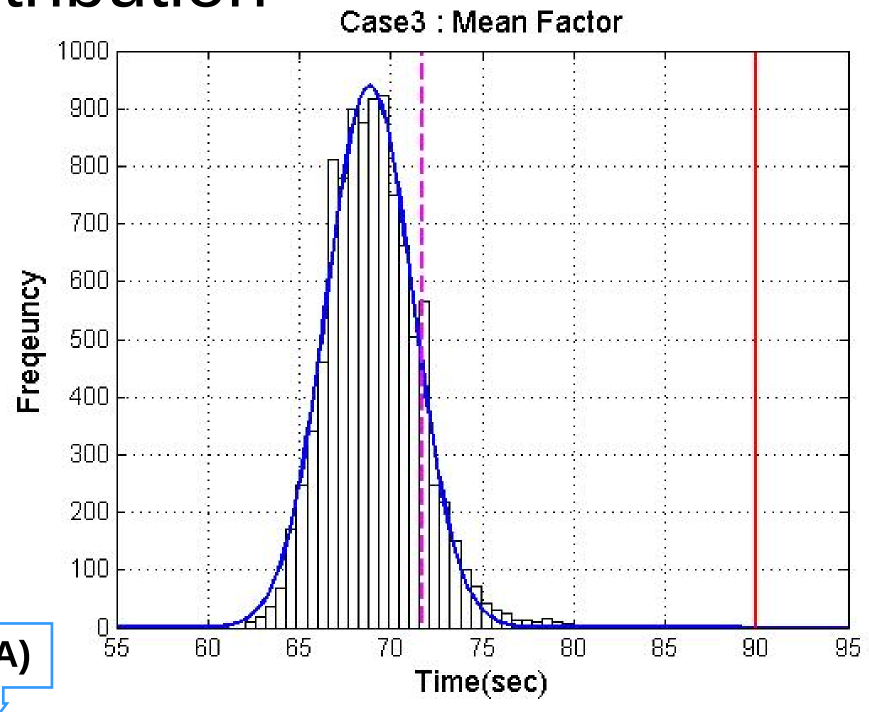
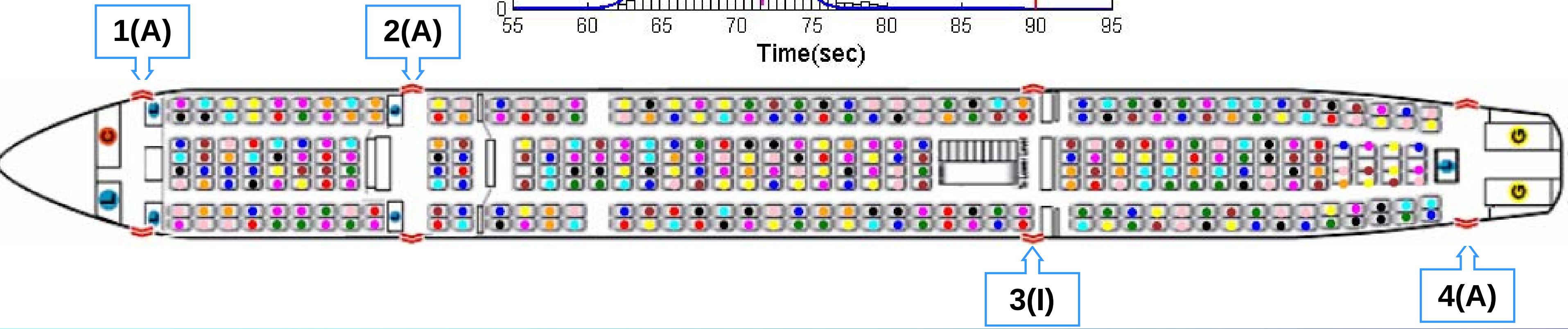
3(I)

4(A)

Validation Case 3

- Time Distribution





Validation Case 4

- Wide Body Vehicle
- 440 Passengers
- Used 74.4 sec
- Opened doors: L1,L2,L3,L4

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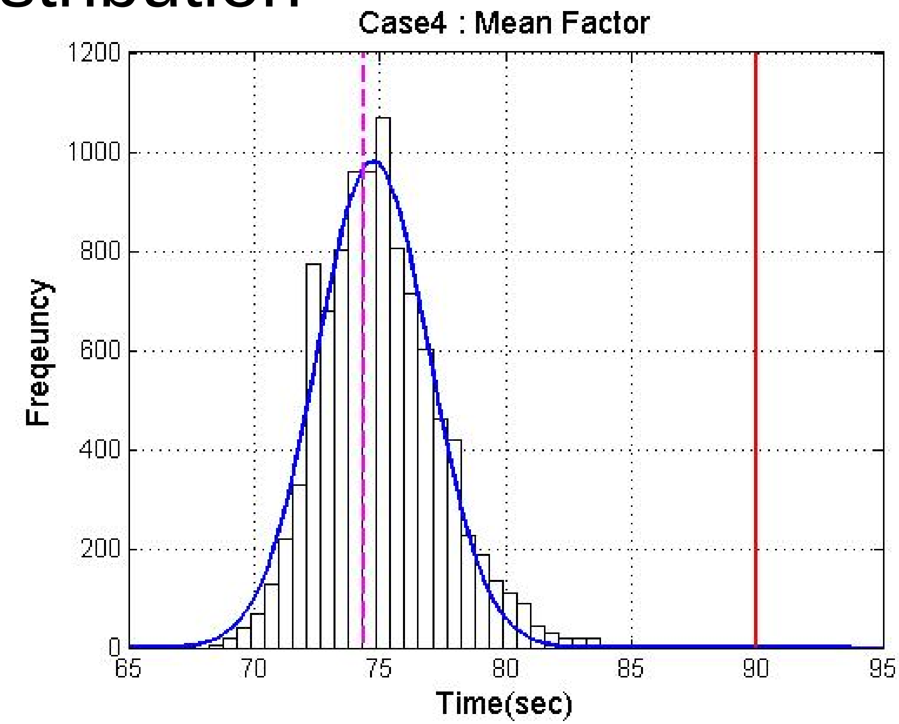
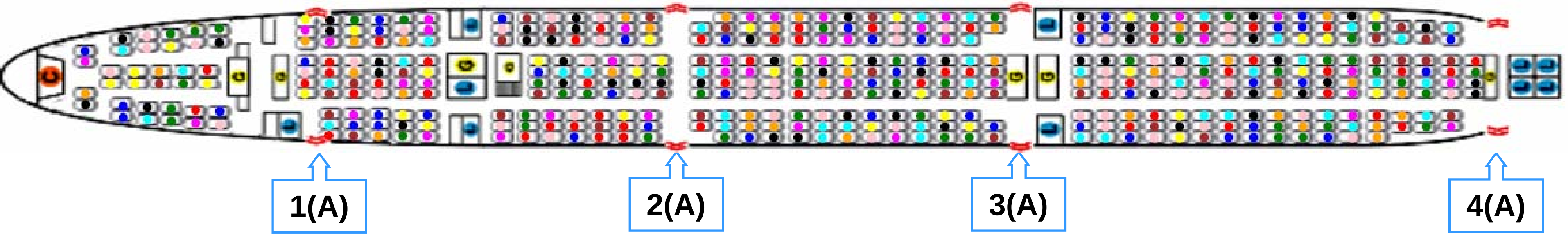
1(A) 2(A) 3(A) 4(A)

Validation Case 4

- Time Distribution





Validation Case 5

- Narrow Vehicle
- 159 Seats, 149 Passengers
- Used 64.1 sec
- Opened Doors: R1,R2,R3

1(C) 2( ) 3(C)

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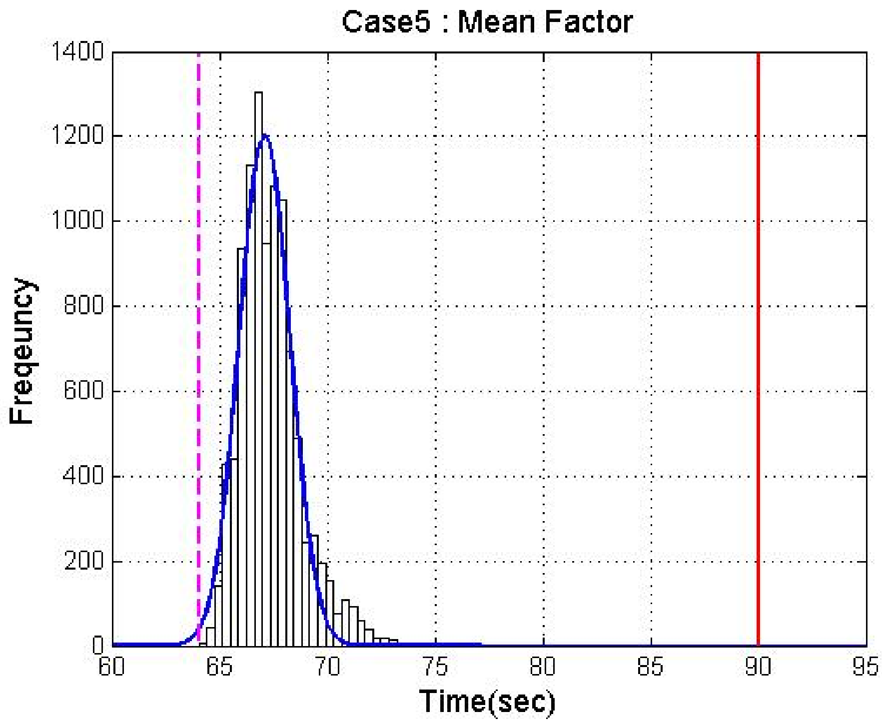
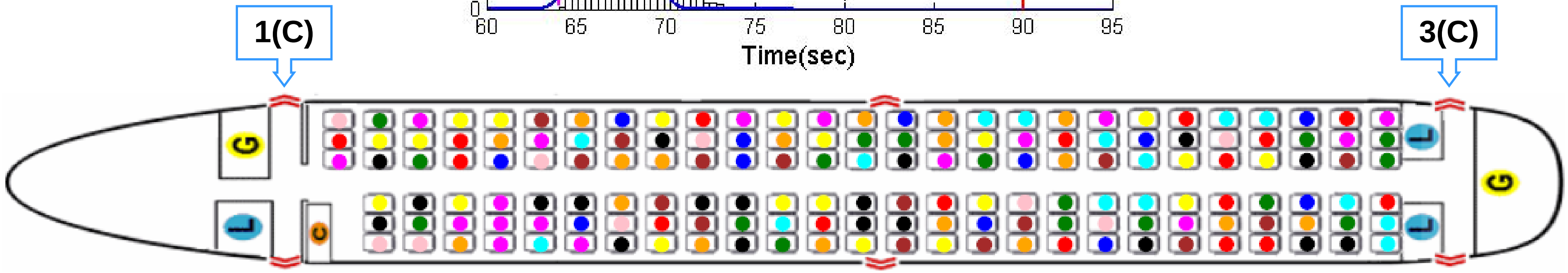
Validation Case 5

- Time Distribution





Validation Case 6

- Narrow Vehicle
- 188 Seats, 188 Passengers
- Used 78.5 sec
- Opened Doors: R1,R2,R3,R4

1(C)

2( ), 3( )

4(C)

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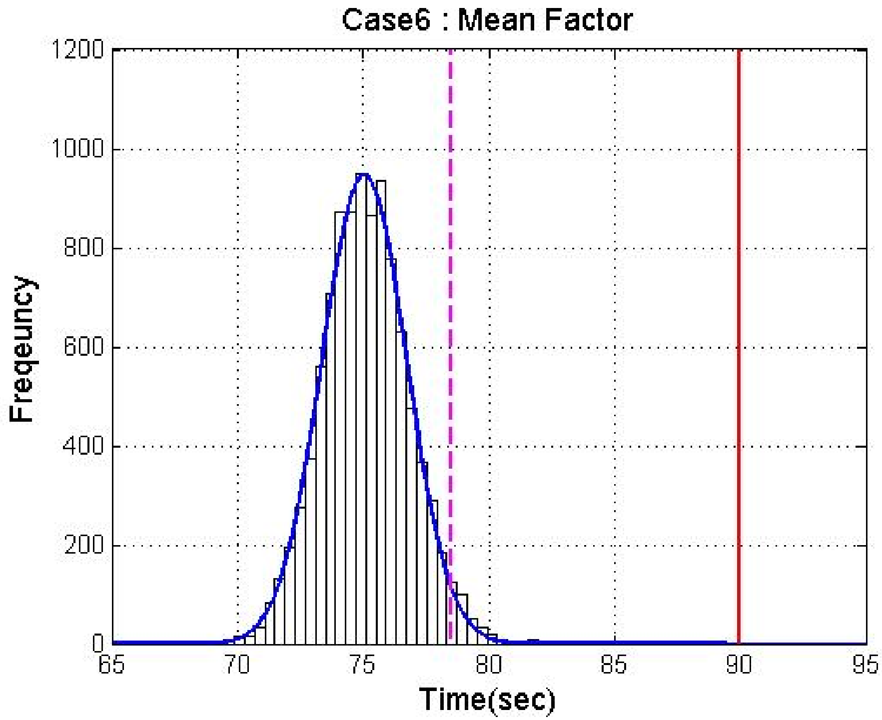
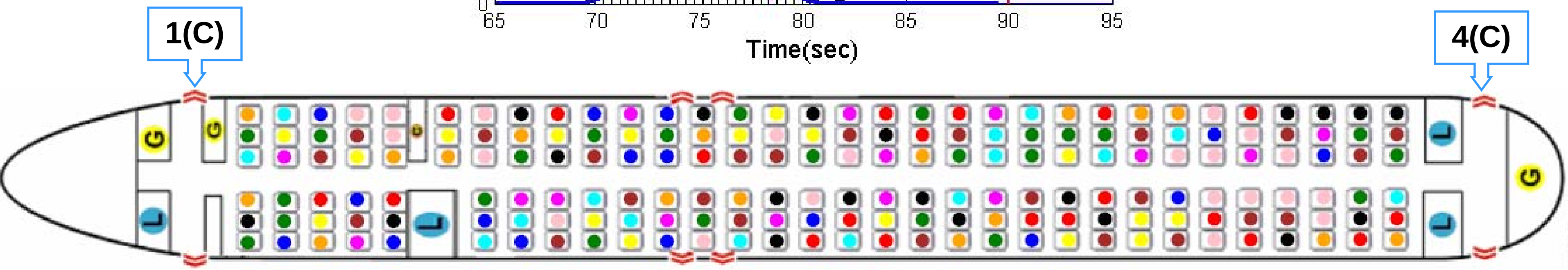
Validation Case 6

- Time Distribution





Typical Evacuation Simulation

- Wide Body Vehicle: Boeing B777
- Typical 348 seats in three class configuration
- Equipped with 4 pairs of type A doors
- Average evacuation time: 44 seconds when all exits are functional

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Evaluation of Egress Assistive Device Using Computer Aided Simulations

Evaluation of Door Assistive Device

- Door Operating Issues
  - Door opening mechanism jam
  - Slide failed to inflate
  - Passenger unable to operate the door
    - Panic, low light, etc.
- Door Assistive Device
  - Restore the efficiency of egress
  - Parameters
    - Device deployment time, final recovered egress efficiency
- Monte Carlo Simulation
  - Parameters
    - 90% Occupancy, 13 sec delay, several door configurations

Simulation on the Worthiness

- Narrow Body Vehicle
  - Airbus A320
  - 148 seats, 133 passengers, two class setup
  - Device placement
    - Single door blockage
    - Multiple door blockage
- Wide Body Vehicle
  - Boeing B777
  - 347 seats, 312 passengers, three class setup
  - Device placement
    - Single door blockage
    - Multiple door blockage

Narrow Body Vehicle

- Single door blockage (F)

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- Multiple door blockage (F,M2,R)

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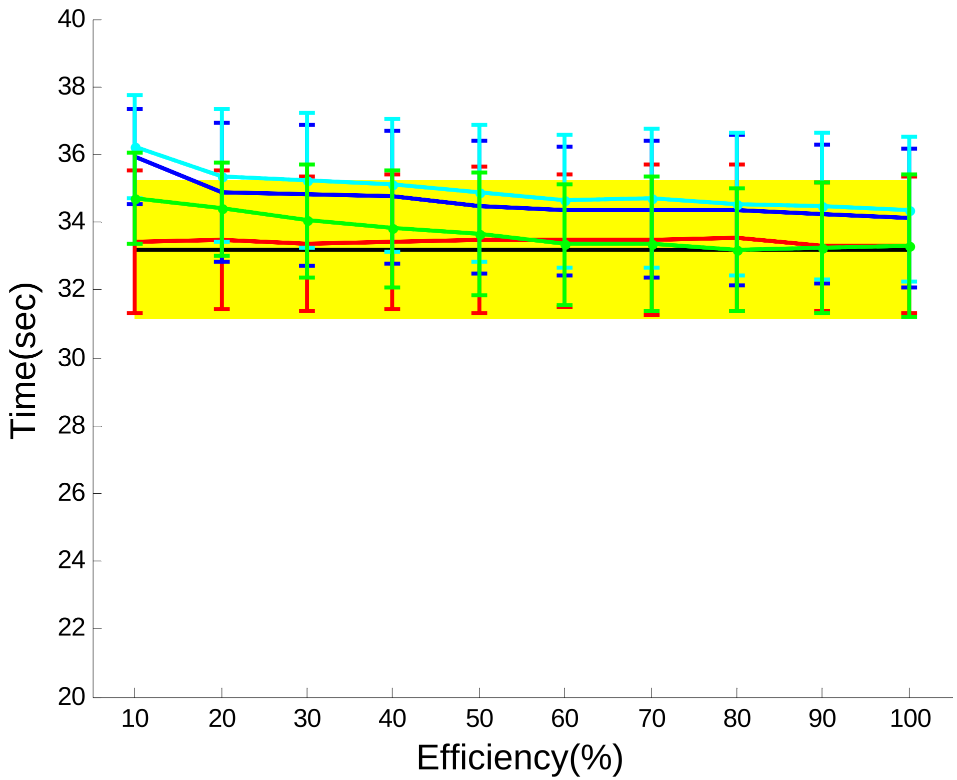
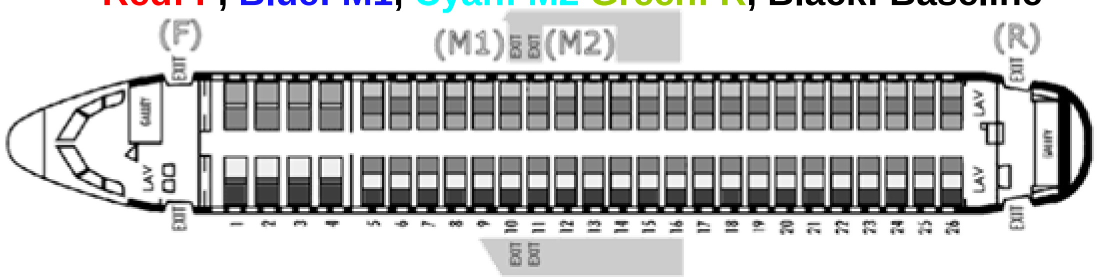
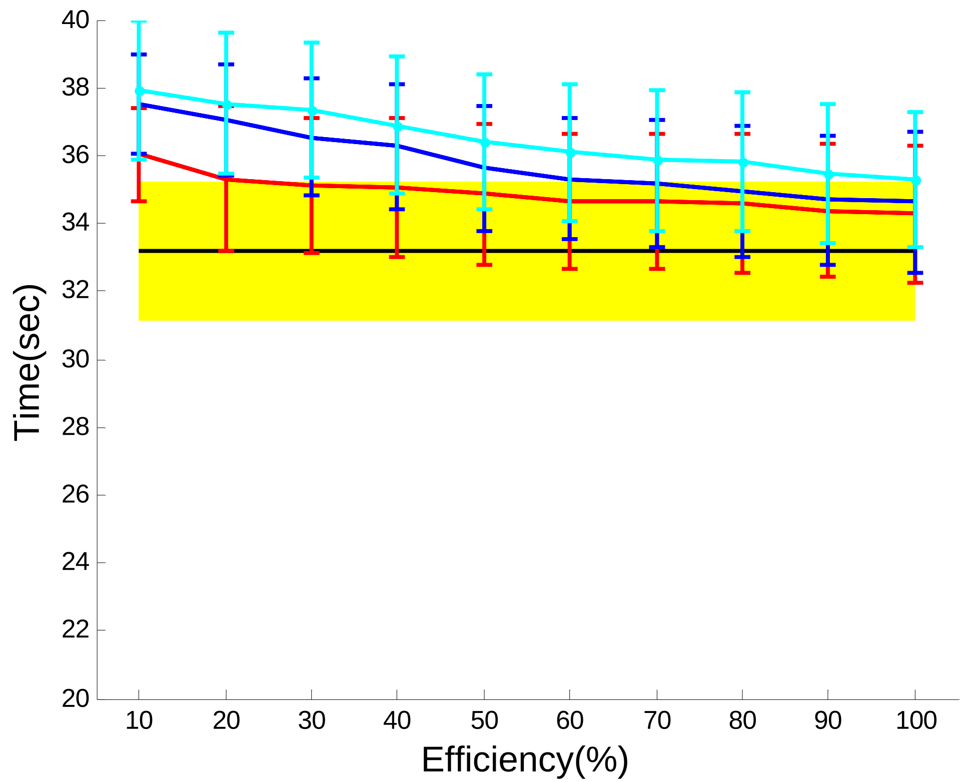
Worthiness of D.A.D. *(single door)*



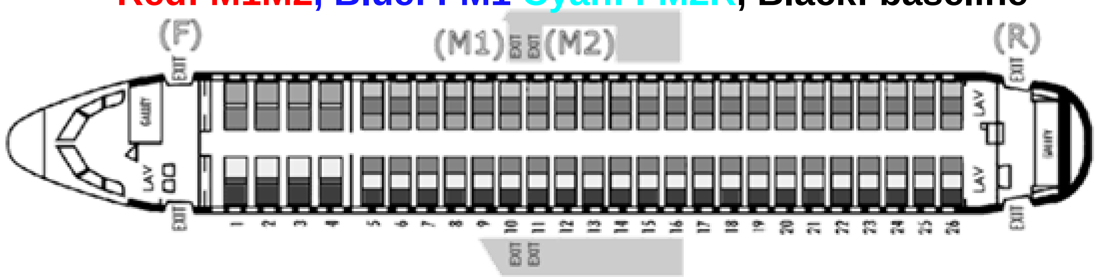
Red: F, Blue: M1, Cyan: M2 Green: R, Black: Baseline



Worthiness of D.A.D. *(multi door)*



Red: M1M2, Blue: FM1 Cyan: FM2R, Black: baseline



Wide Body Vehicle

- Single door blockage (M1)

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- Multiple door blockage (F,M1,M2)

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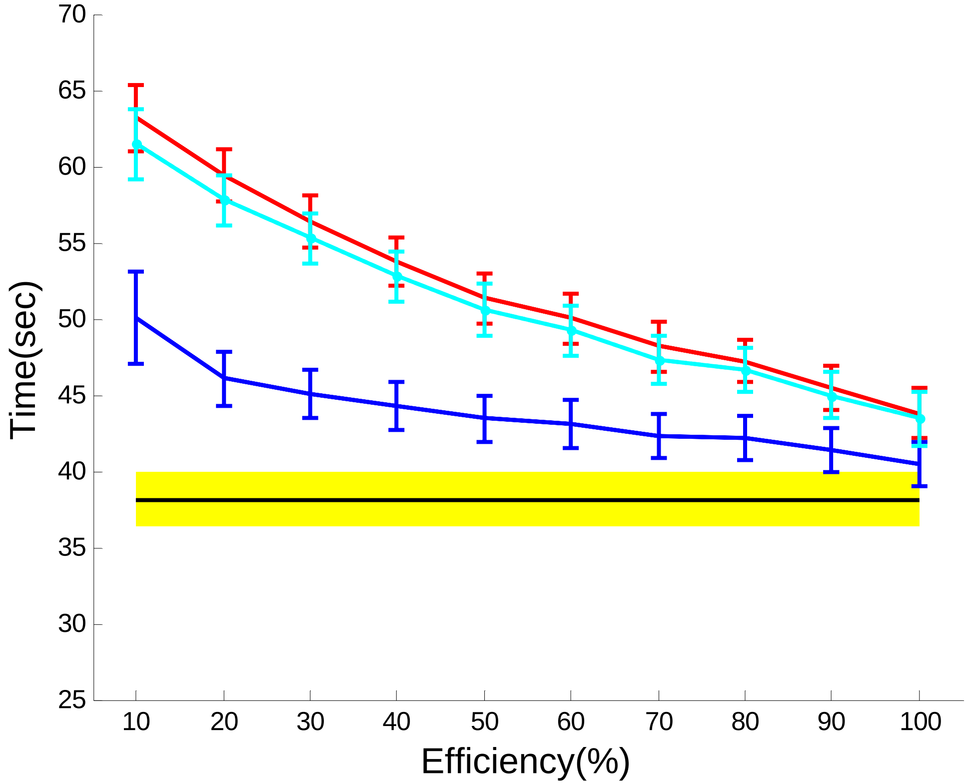
Worthiness of D.A.D.



Blue: M1, Cyan: M1M2,Red: FM1M2

Conclusion

- A computer simulation program on emergency evacuation has been developed and validated to be accurate.
- This program can be used to estimate the evacuation time under different emergency scenarios.
- Door Assistive Device have been modeled. Our simulations show that it can be effective on wide body vehicles.