Study of Optimal Passenger Flow Pattern During Emergency Evacuation

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Computer Simulation Modeling

- In order to simulate a realistic passenger flow pattern during an evacuation, we need:
  - Structure Modeling
    - Doors, aisles, seats, lavatories, galleys and their locations
  - Passenger Reaction Modeling
    - Human factors
    - Decision making model
  - Human-Structure / Human-Human Interaction
    - Knowing the environment
    - React to the situation
    - Achieve the final goal → SAFETY

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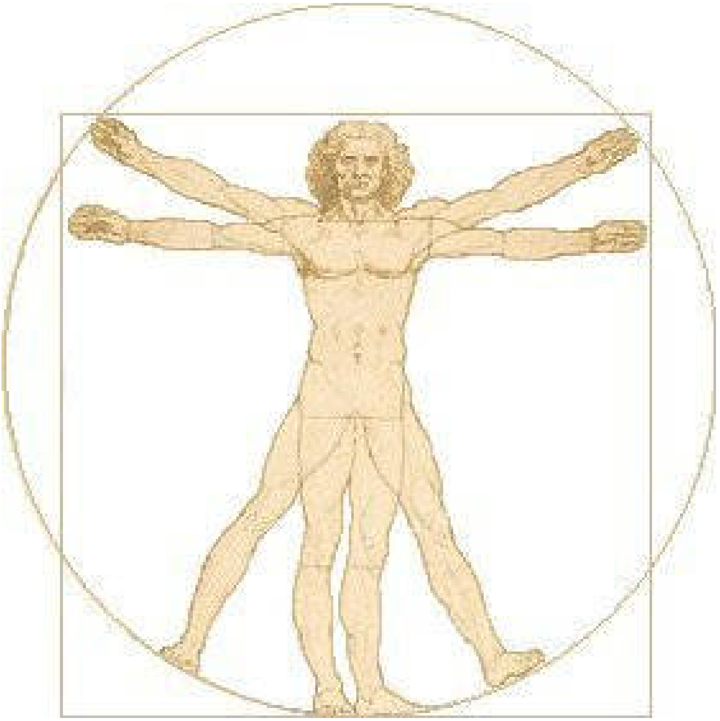
Passenger Reaction Modeling

- Passengers Factors and Behavior*
  - Age
  - Gender
  - Height
  - Waist size



- Decision Making Model
  - Sense of the environment
  - Crew instruction
  - Game theory

Passenger Reaction Modeling*

- Age
  - As may be expected the younger individuals are faster and thus they escape from the airplane quicker.

Age (years)	Mean Time (s)
18-22	1.34
23-32	1.44
33-42	1.57
43-52	1.71
53-65	2.01

- Gender
  - The effect of gender on evacuation is significant

Gender	Mean Time (s)
Male	1.49
Female	1.7

McLean, et al. (2002)

Passenger Reaction Modeling*

- Height
  - Effects of height is not signification for individuals over 5.4 feet
- Waist Size
  - The larger the waist size the more time is required to evacuate from an airplane.

Height (in)	Mean Time (s)
57-64	1.74
65-66	1.59
67-68	1.52
69-71	1.55
72-79	1.58

Waist Size (in)	Mean Time (s)
23-31	1.35
32-34	1.43
35-38	1.51
39-41	1.72
42-62	1.96

McLean, et al. (2002)

Human-Human Interaction

- Impeding Effect
  - Passengers moving slower in the aisles impede other passengers
- Overtaking Effect
  - Faster passengers can overtake the slower ones in the open space in the vehicle
- Flight Crew Redirection
  - Evenly distributes the passengers to all the doors
  - Achieves minimal door idle time
  - Reduce total time of evacuation

Human-Structure Interaction

- Obstacles
  - There might be pillows, blankets, etc. in the aisles
- Luggage
  - Some passenger might want to retrieve their belongings during evacuation
  - Luggage reduces speed
  - If left in aisle, it impedes other passengers
- Illumination
  - Low illumination conditions slows passengers
- Environmental Hazards

Passengers' Strategy Modeling

- Assumptions on passengers
  - Are not fully aware of the status of the vehicle
  - Have limited range of visibility to the exits
  - Tend to stay in a decided direction unless other direction shows a significant advantage
  - Have different factors that affect mobility
  - Are free to make their own decision on which door to go to, and are able to change target door at any time based on one's estimation of which can get one out the fastest

Crew's Strategy Modeling

- Assumptions on crew members
  - Are nearly fully aware of the status of the vehicle,
  - Also have limited range of visibility to the exits,
  - Passengers will follow crew's instruction/direction unless one finds out it is infeasible to go to the directed door or the path is clogged,
  - Crew should be around the exits or the key locations to redirect passengers,
  - Crew is able to direct passengers according to the dynamic status of the vehicle during an evacuation,
  - Crew is able to encourage and push passenger through the way out of vehicle.

Decision Making Model

- Passengers' Strategy
  - Find a nearest door to go to,
  - Observe how the current line is moving,
  - Switch to other exits when time to evacuate from another exit could be significantly less.
- Flight Crew's Strategy
  - Evenly distributed passenger flow to all useable exits,
  - Direct passengers to go to less crowded exits.
- Confliction Resolution
  - Mobility and other factors.

Crew's Redirection Effects

Simulation Configuration

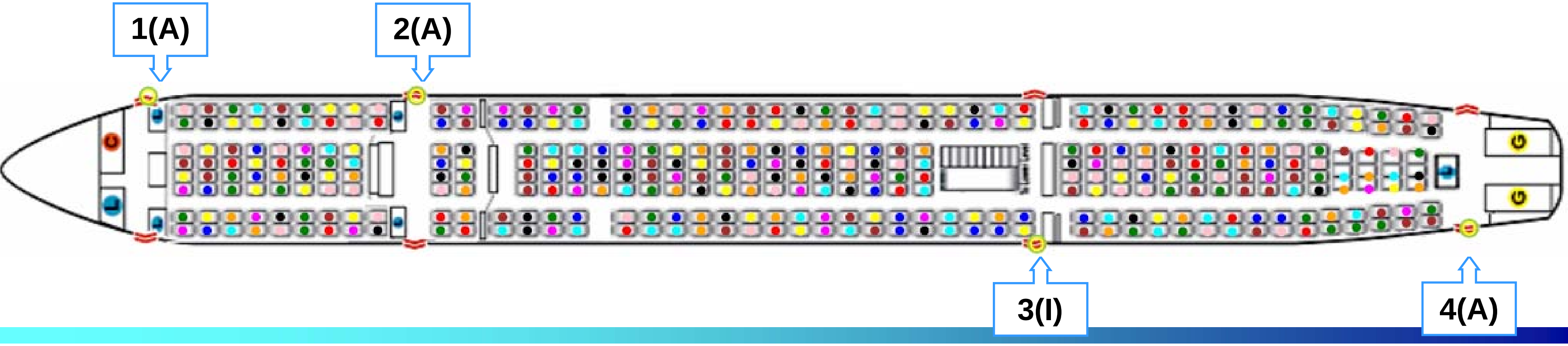
- Passenger Distribution
  - 100% Occupancy
  - Young male, old male and young female, old female

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

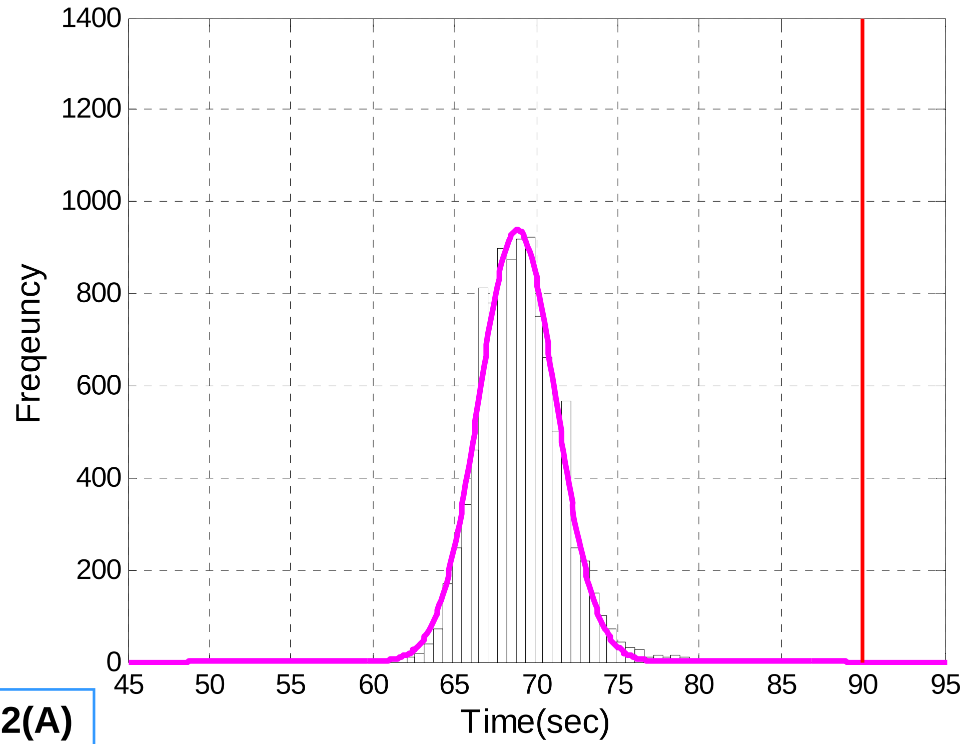
- Crew Positioning
  - Crew members are placed near the exits where they normally sit in a vehicle
  - Crew members may be placed at some key locations
  - The locations host crew members are marked with letter “C” in the vehicle figure

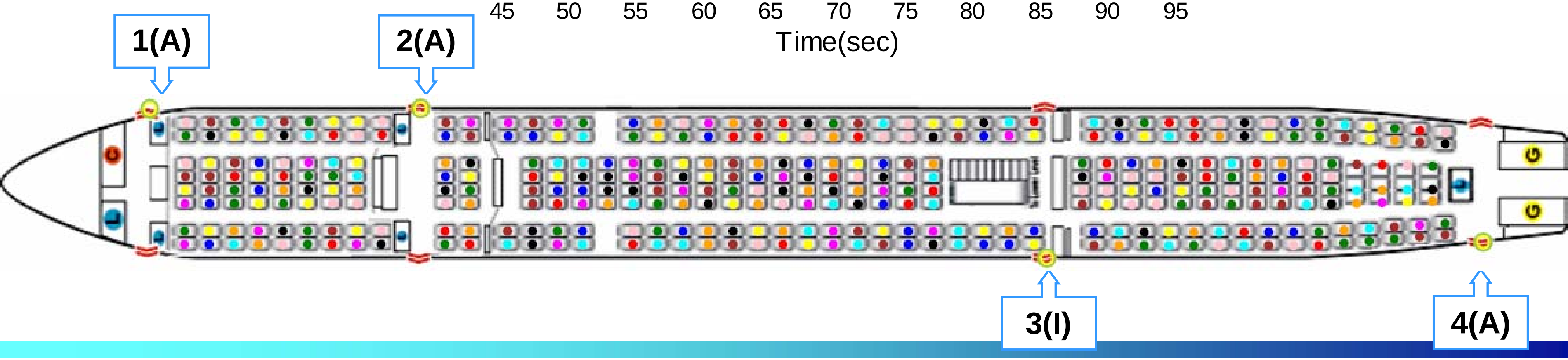
Case Study I: Wide Body Vehicle

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



Case Study I: Wide Body Vehicle





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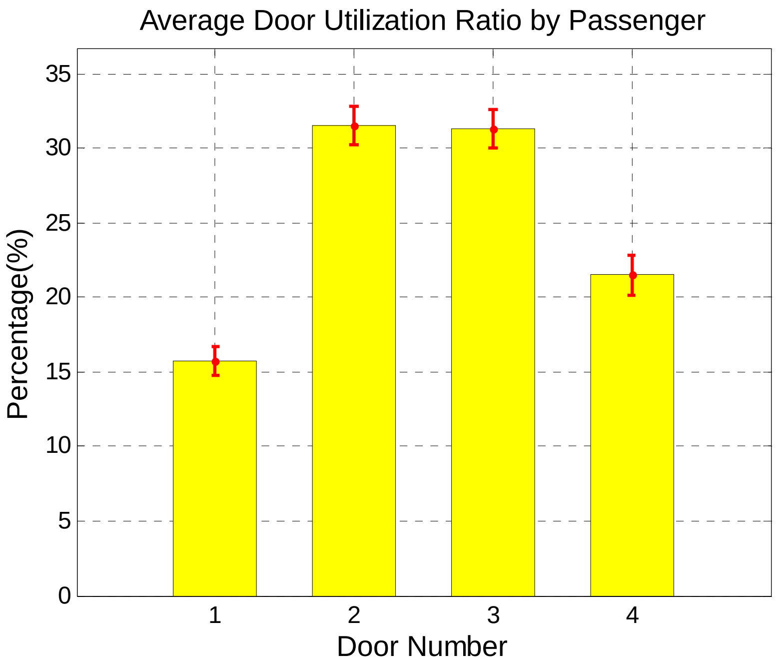

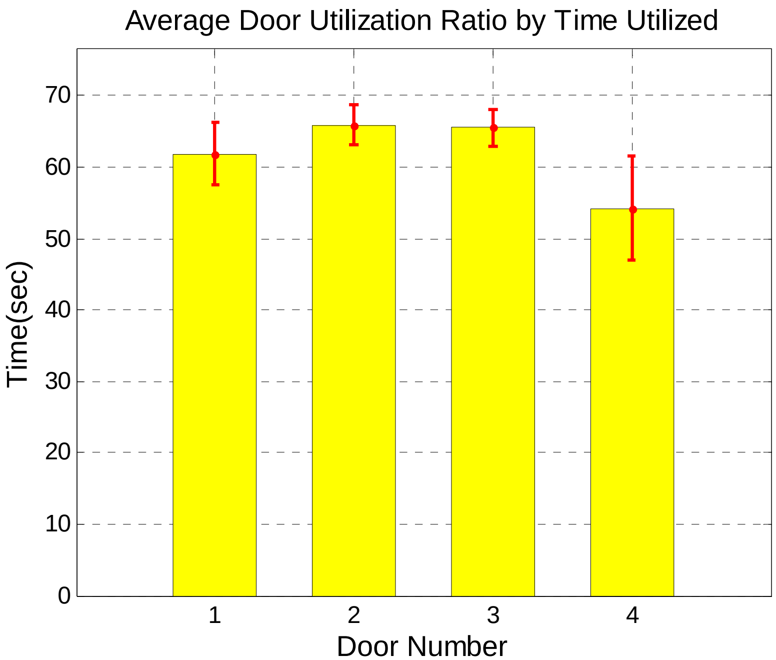

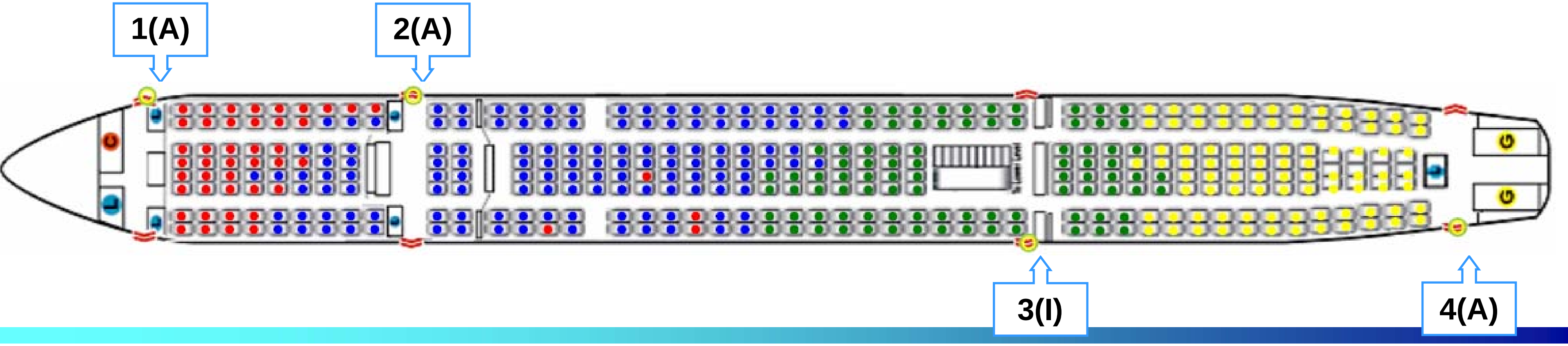

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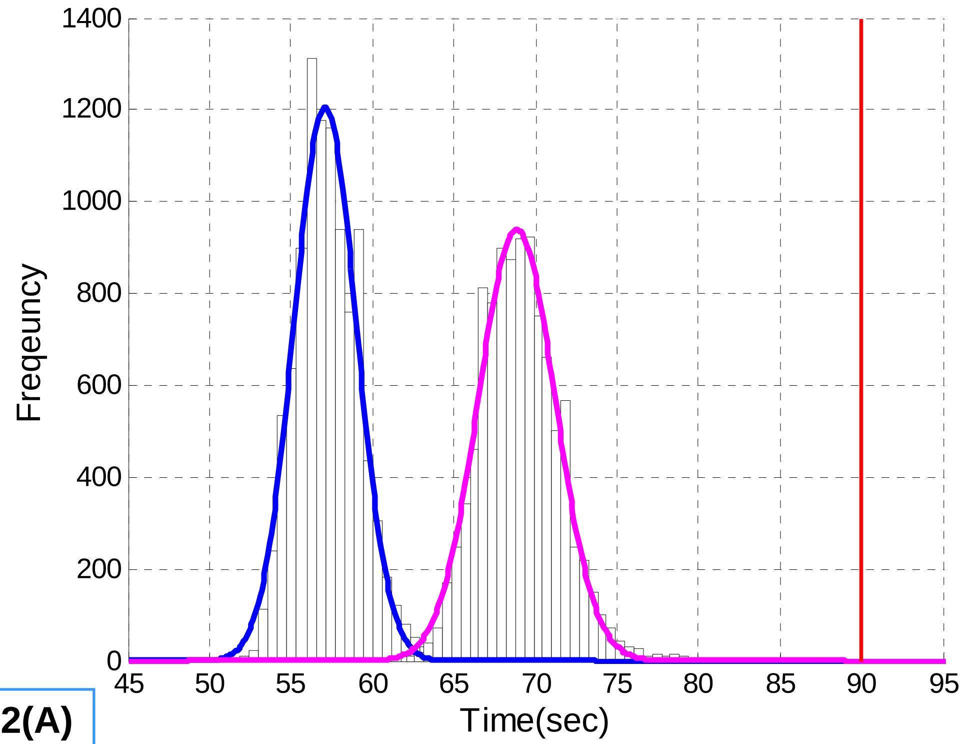

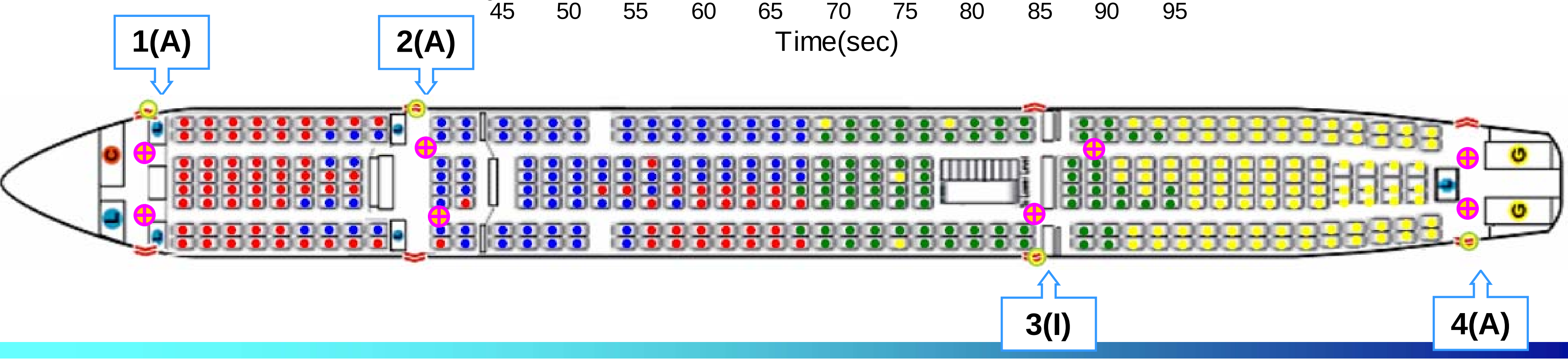

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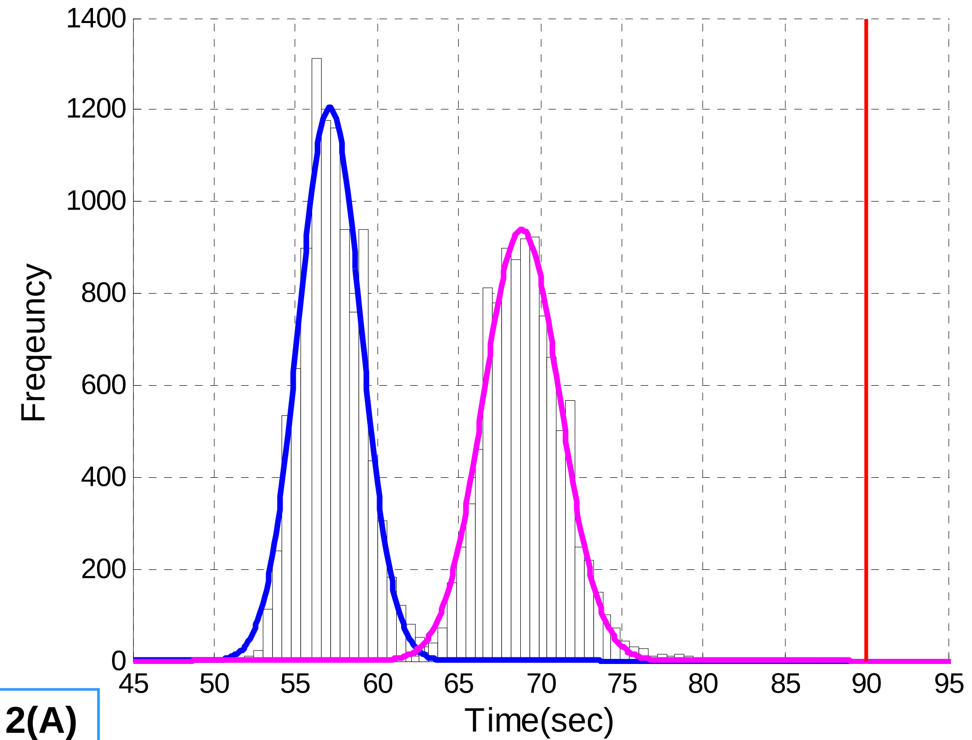

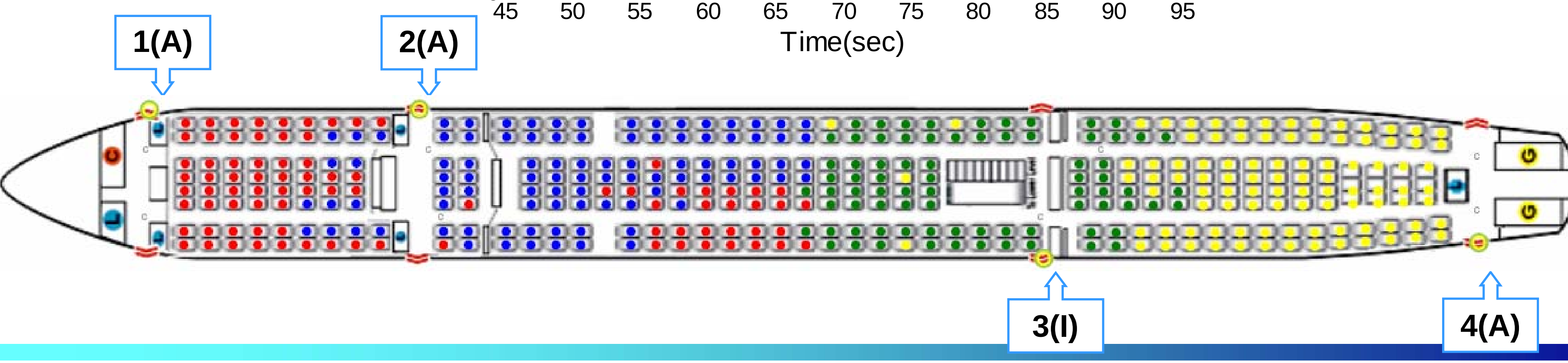

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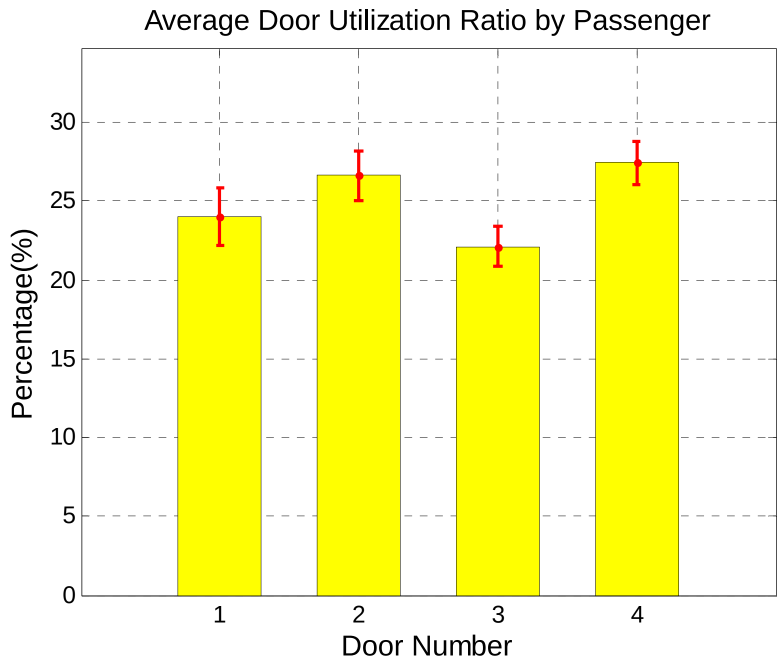

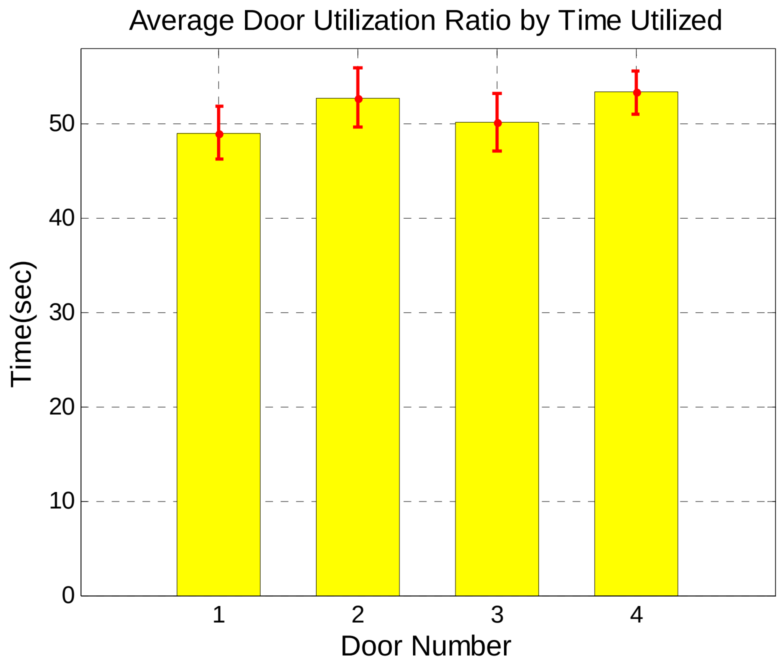

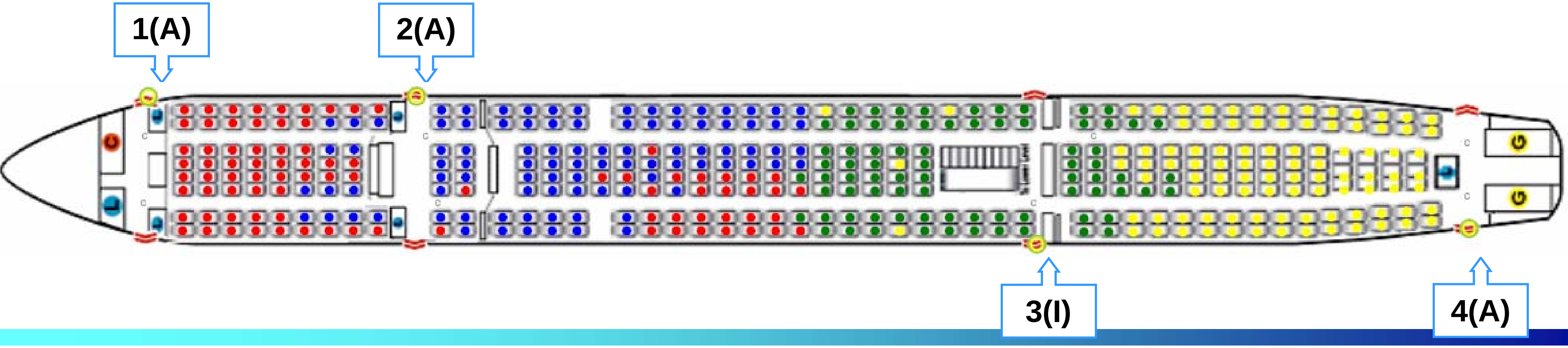

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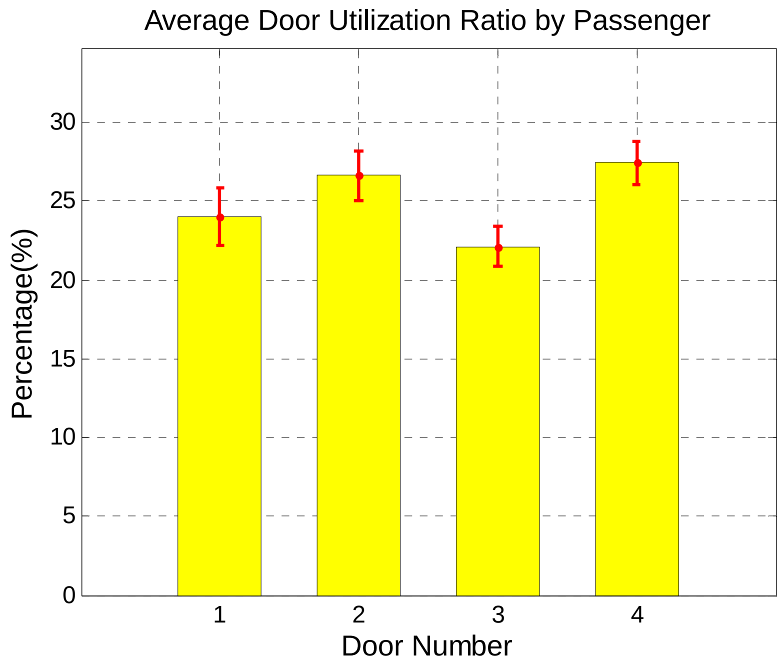
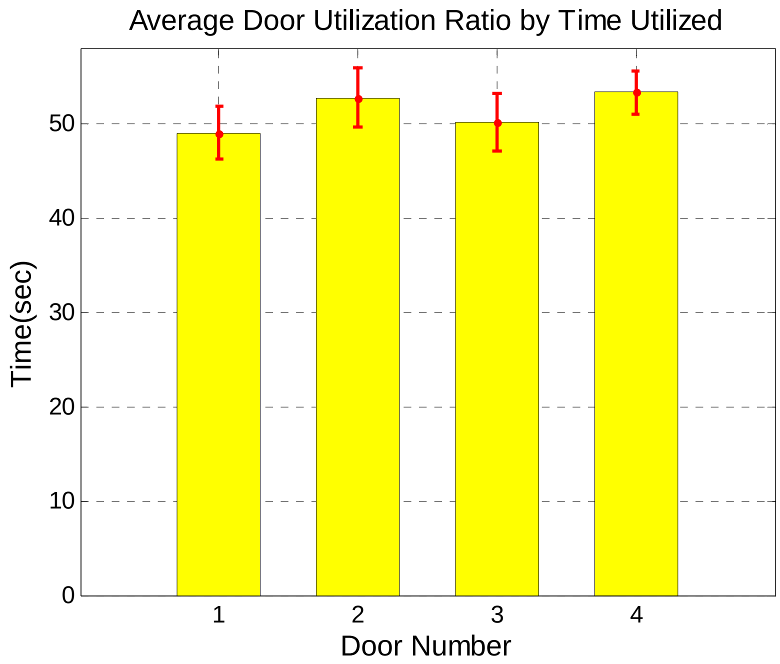
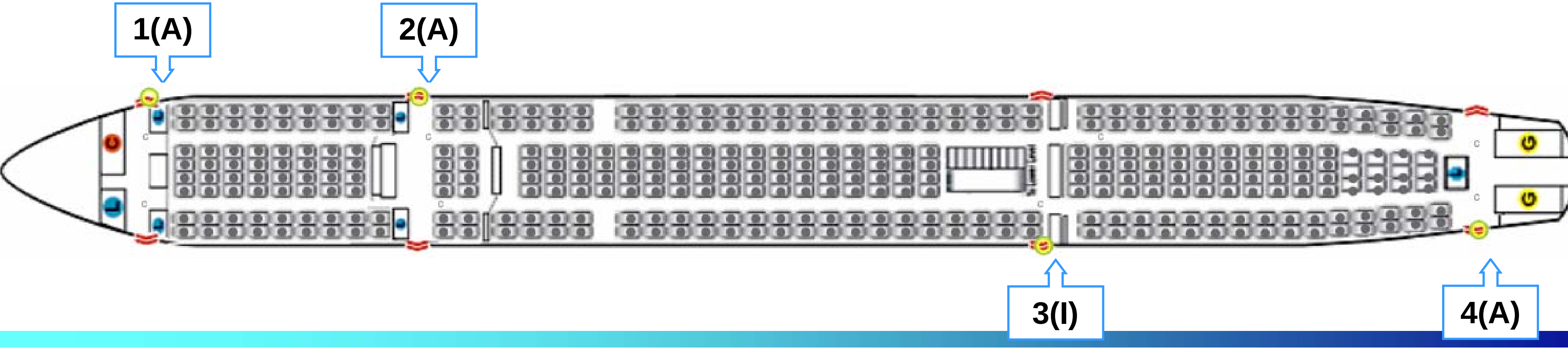
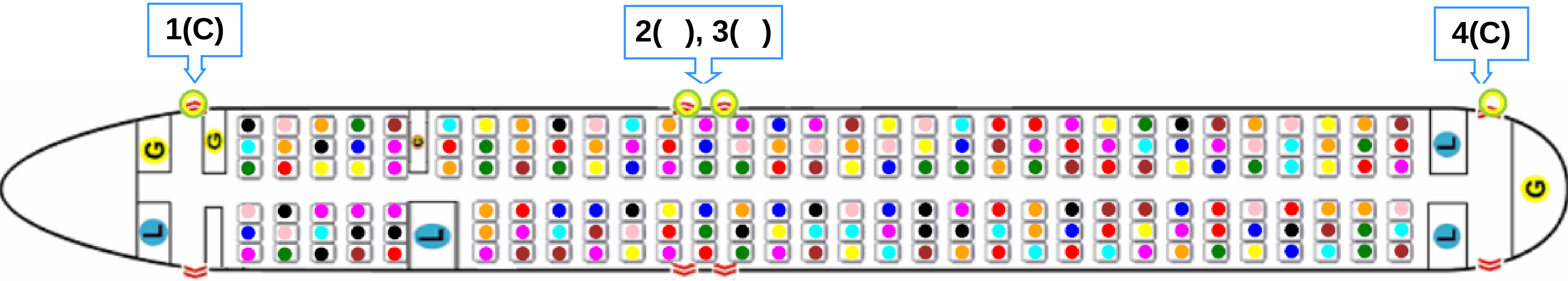






Case Study II: Narrow Body Vehicle

- Narrow Vehicle
- 159 Seats, 188 Passengers
- Opened Doors: R1,R2,R3,R4



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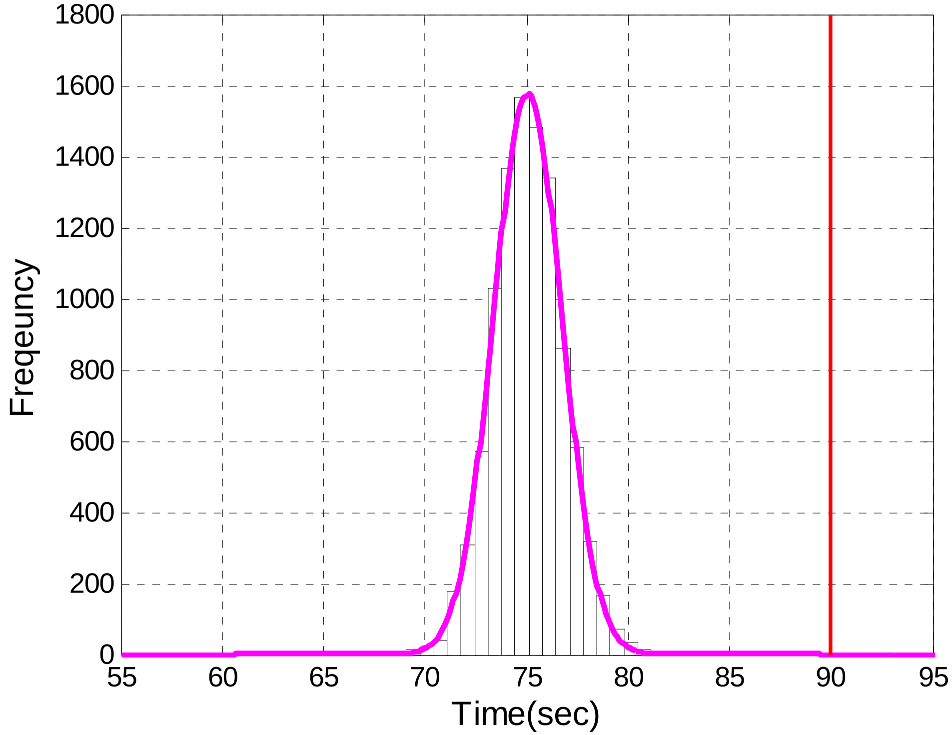

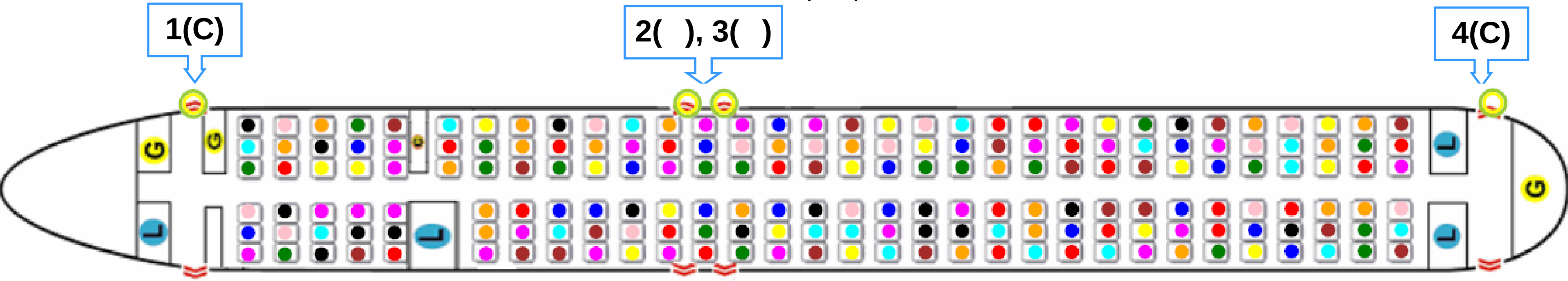

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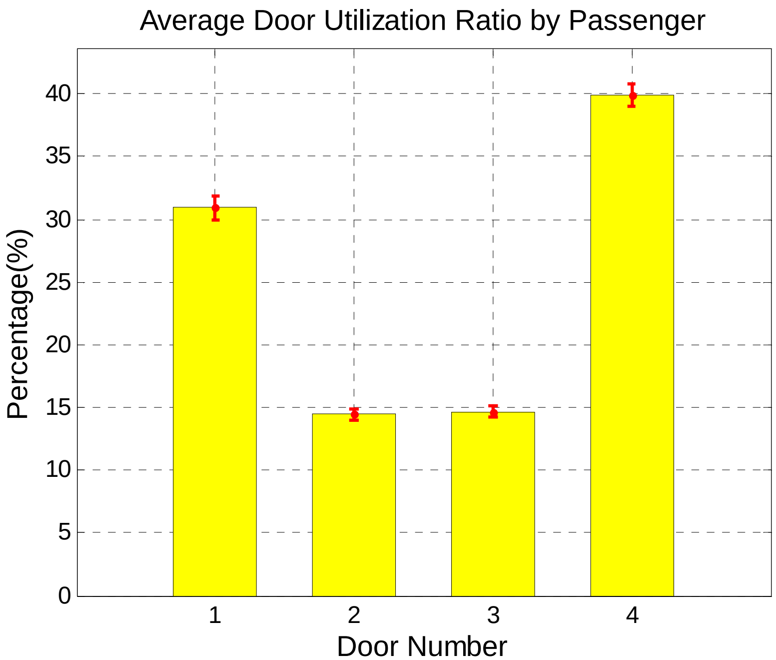

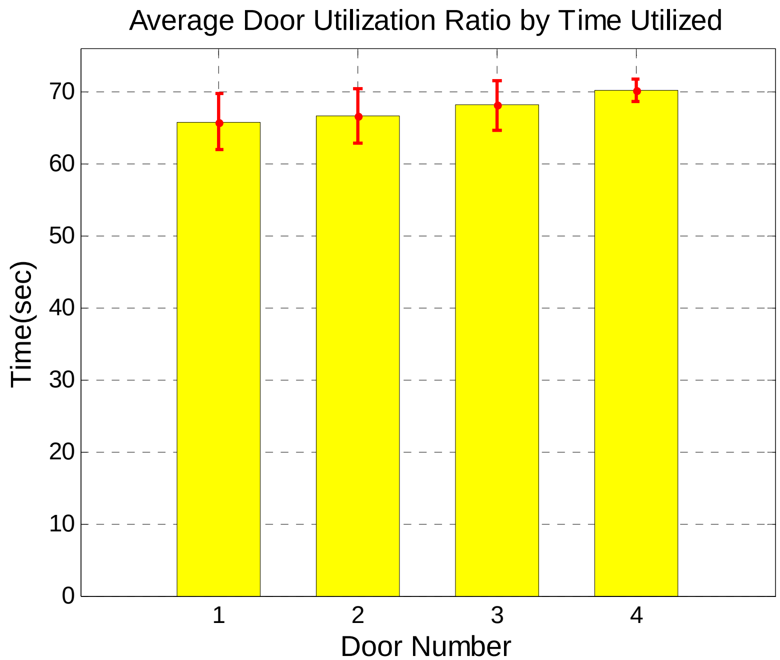

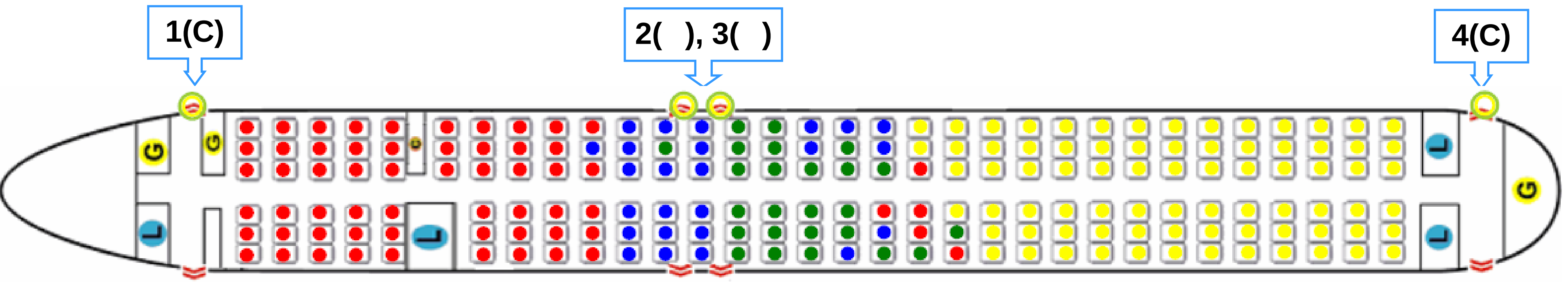

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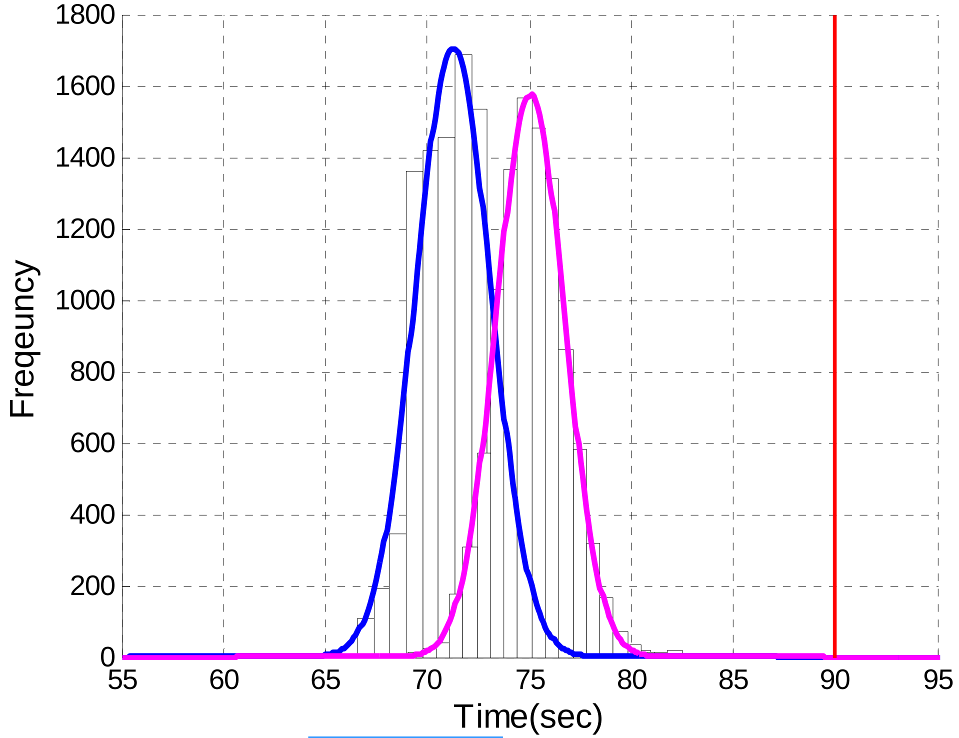

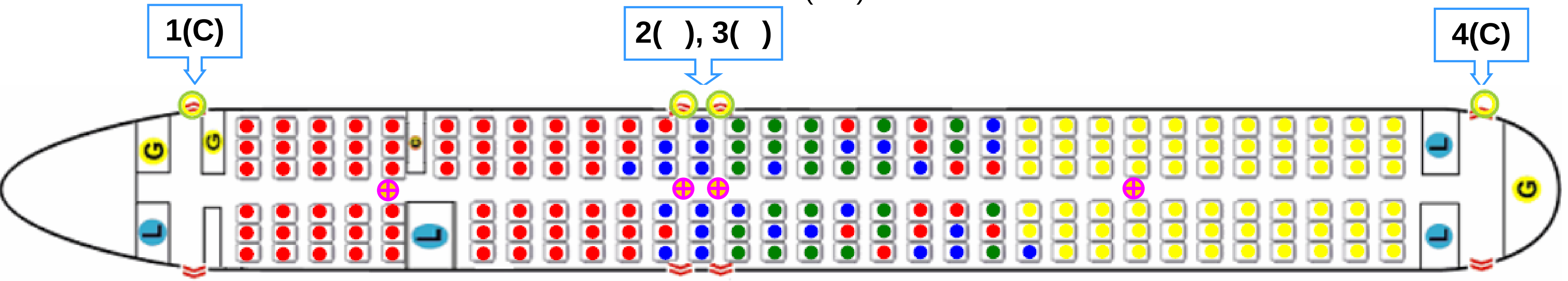

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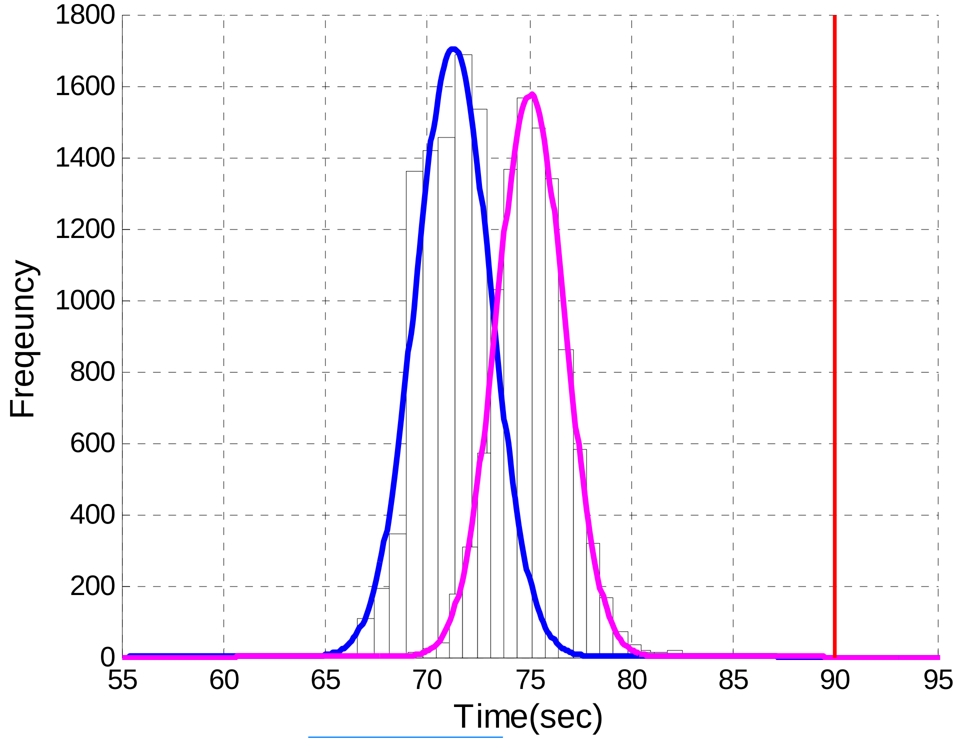

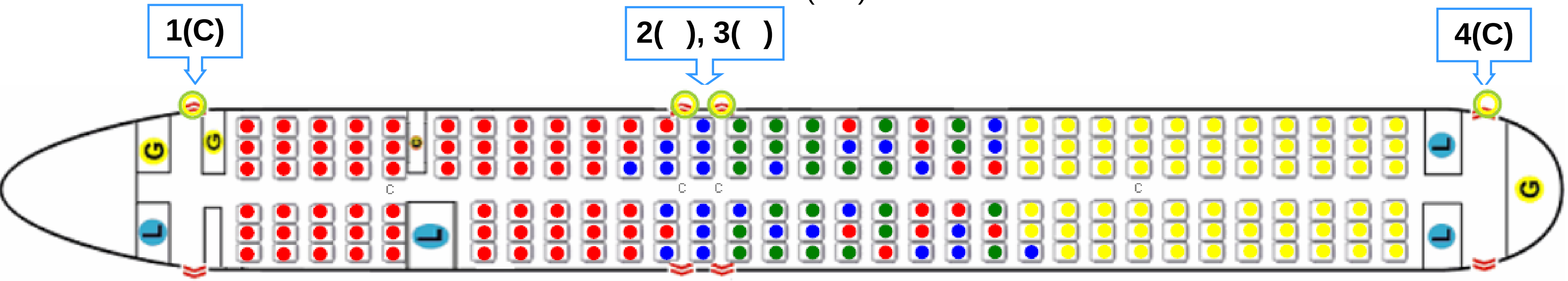

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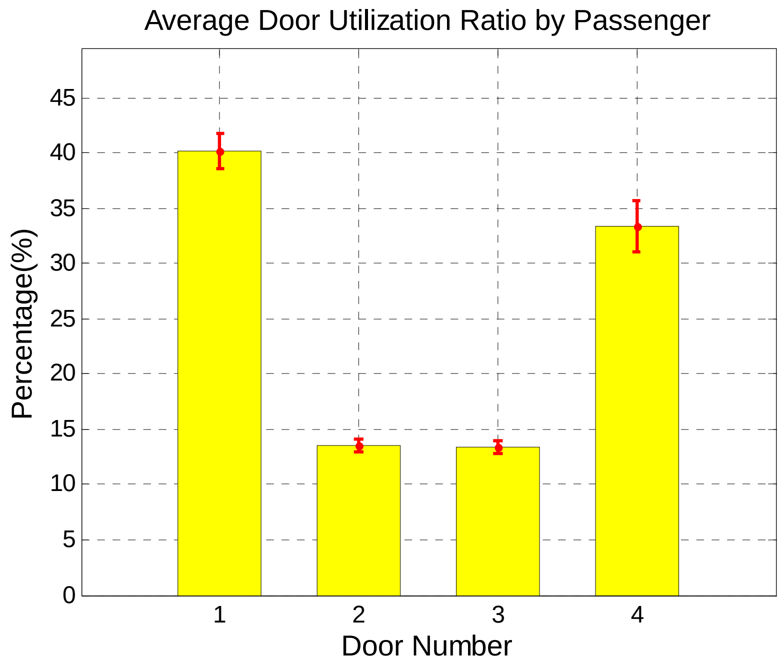

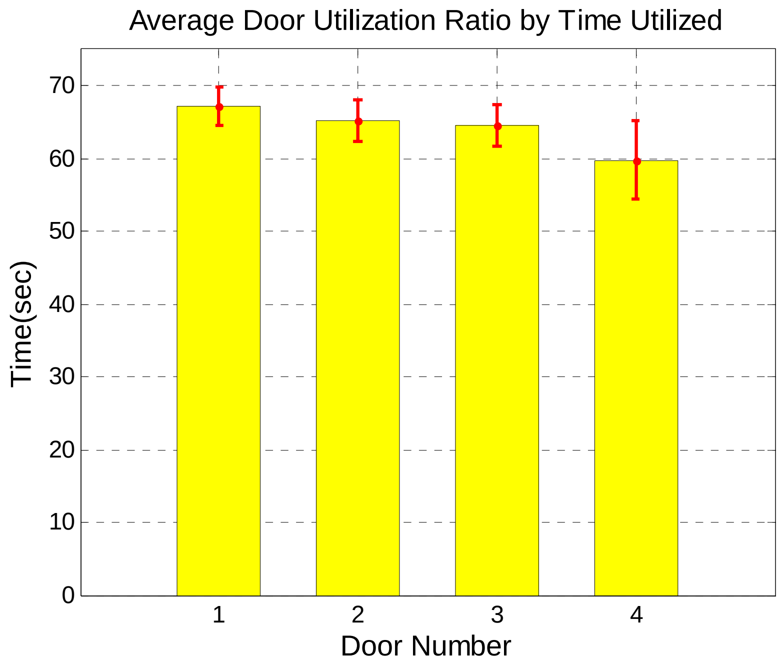

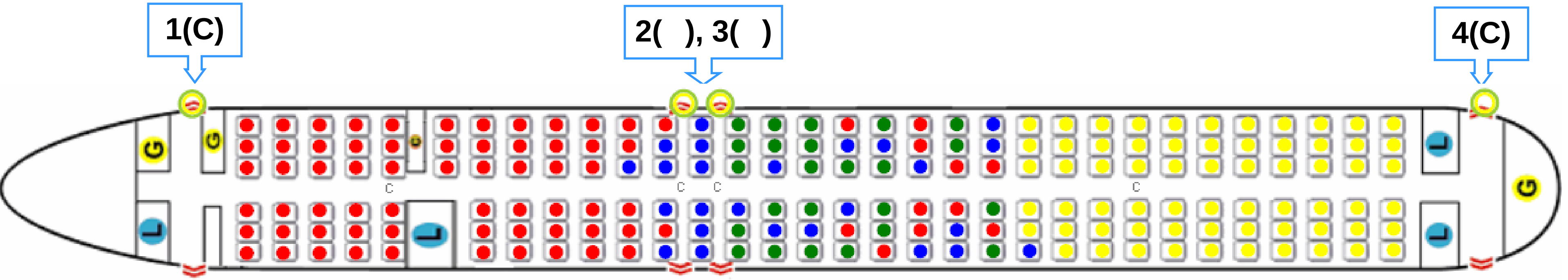

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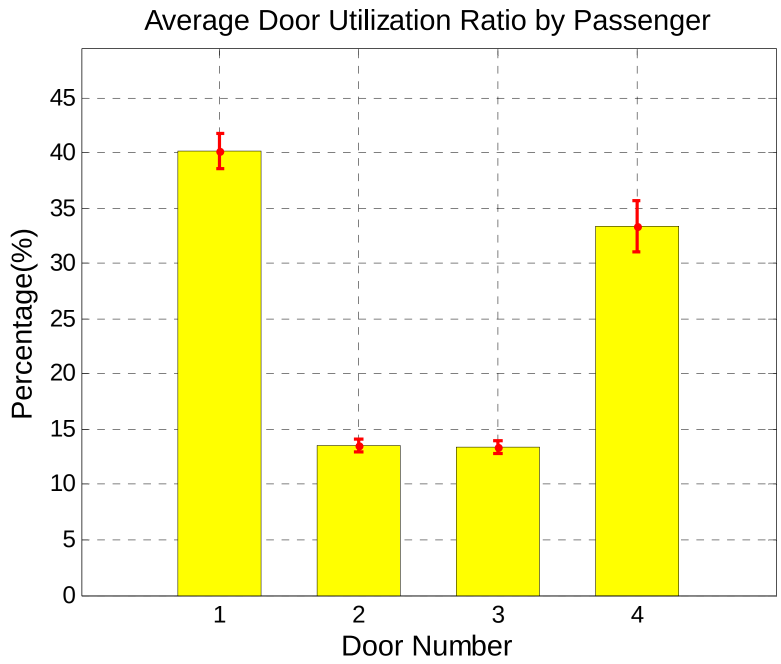

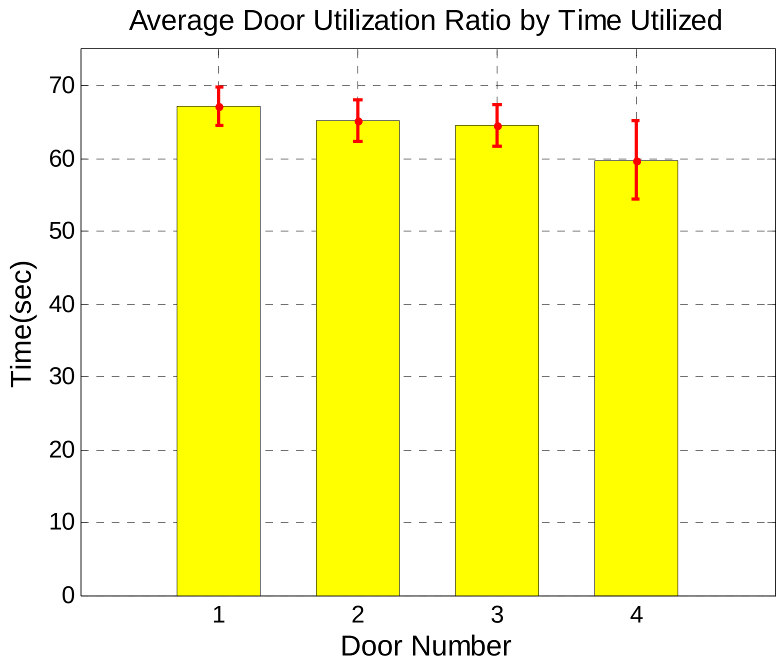

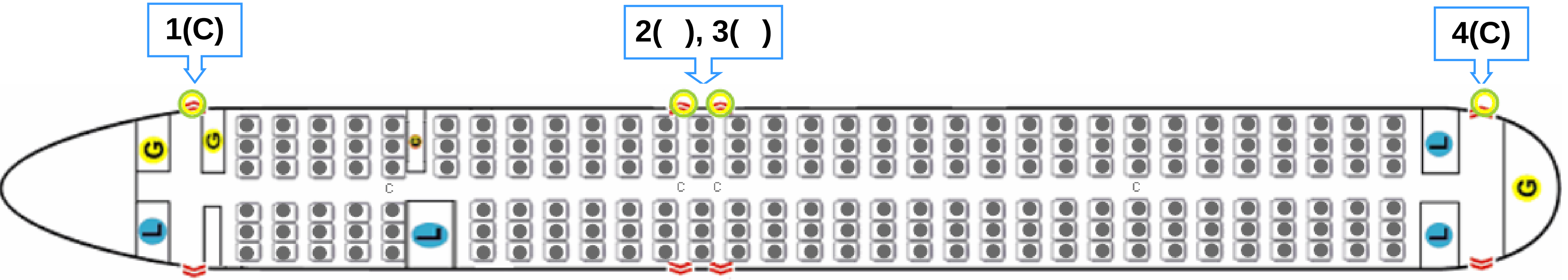

Conclusion

- A computer simulation based aircraft evacuation program has been developed.
- Human factors are implemented into the passenger reaction modeling. Human-human interactions, including impeding, overtaking and flight crew re-direction are also included.
- Flight crew plays a very important role in passenger evacuation flow pattern in wide-body vehicles but with limited effects on narrow-body vehicles.