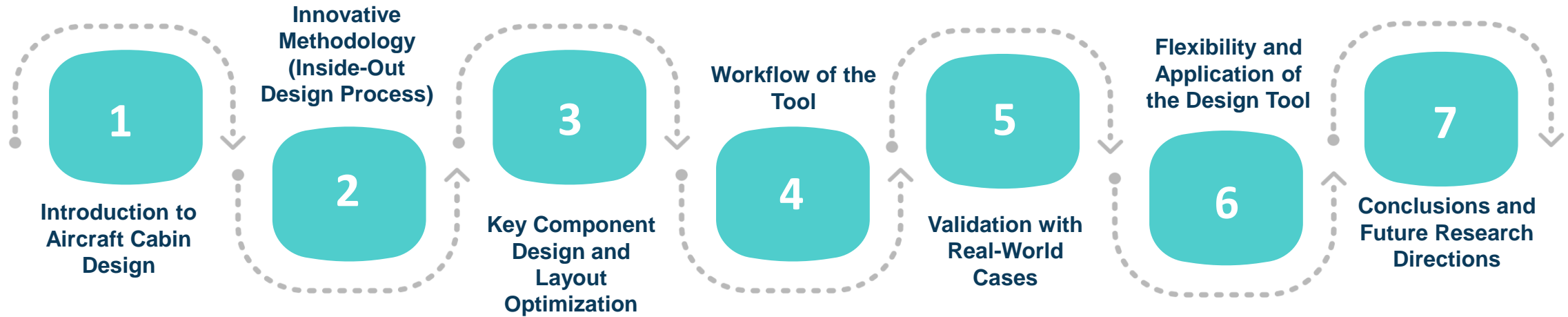


# Advancing Aircraft Interior Design: Automated Solution for Optimized Cabin Layout in Modern Aviation

Yash Vijaykumar Gandhi  
Supervisor: Marc Engelmann M.Sc.

Willy-Messerschmitt-Strasse 1,  
Taufkirchen, 13.08.2024

# Agenda



# Introduction to Aircraft Cabin Design

## ➤ Purpose and Objectives:

### Innovate Aircraft Cabin Design:

- Integrate cabin and fuselage design processes for efficiency.
- Develop tools for diverse configurations (Sleeper Class, Group Seating).
- Enable multi-deck layouts and customizable seat arrangements.

## ➤ Current Tools and Challenges:

- **PreSTo:** Excel-based; limited to conventional designs and lacks Open Office compatibility.
- **ParaFuse:** Python-based; enhances comfort but restricted to single-deck and has limited software compatibility.

## ➤ Regulatory Framework and Compliance:

- **EASA Standards:** Ensure safety and environmental responsibility through certification policies.
- **CS25 Regulations:** Define criteria for structural integrity, system functionality, cabin layout, and emergency evacuation.

### Impact and Importance:

- **Compliance:** Ensures optimal design, enhances safety, and is crucial for certification.

# Innovative Methodology: Inside-Out Design Process

## ➤ Importance of the Inside-Out Methodology:

- Passenger-Centric Design
- Customization and Innovation
- Flexibility and Future-Proofing

## ➤ Key Steps in the Inside-Out Methodology:

- **Nose Cone:** Define shape and dimensions for optimized space and features.
- **Middle Section(Primary Focus):** Innovate cabin layout; prioritize comfort, safety, and compliance; optimize exits, lavatories, galleys, and storage.
- **Tail Cone:** Ensure structural integrity and aerodynamic efficiency; integrate with fuselage and cabin.

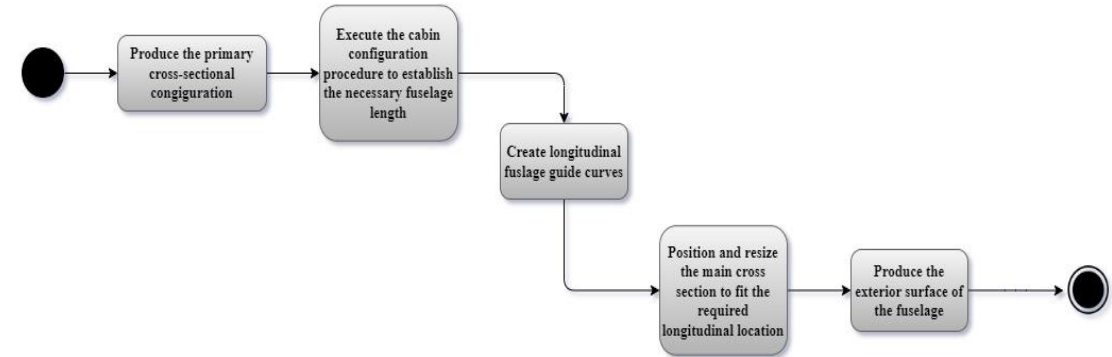


Figure 1 - An overview of the inside-out fuselage design method

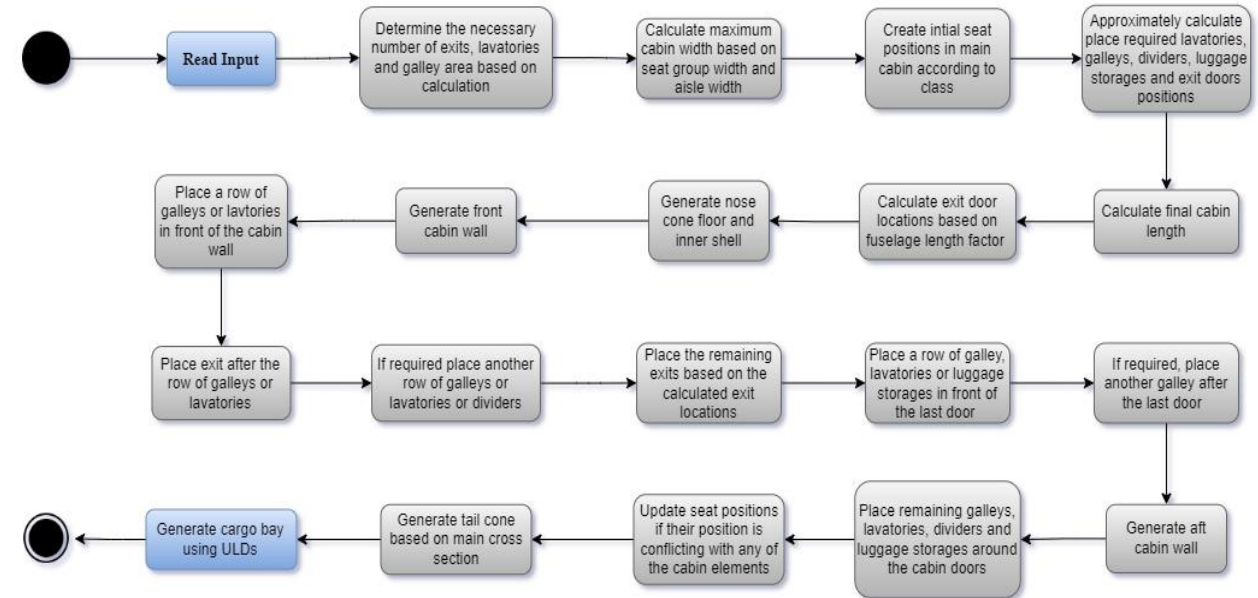


Figure 2 - Inside-out (middle section) cabin configuration process

# Key Component Design and Layout Optimization

## ➤ Emergency Exits:

- Comply with safety standards; place strategically for efficient evacuation.

## ➤ Seating Arrangements:

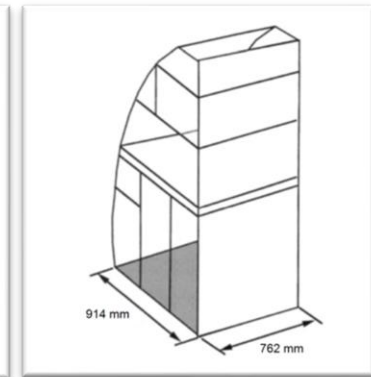
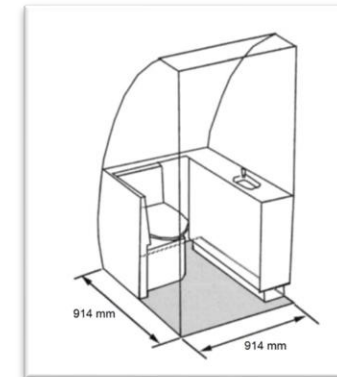
- Maximize comfort and capacity; support various class layouts.

## ➤ Lavatories and Galleys:

- Design for accessibility and convenience; enhance passenger flow.

## ➤ Other Key Components:

- **Cargo Compartments:** Optimize space for luggage and cargo.
- **Cabin Walls and Floors:** Ensure structural integrity and aesthetic design.





# Workflow of the tool

## Comprehensive Workflow of CPACS-Python Integration

### ➤ CPACS (Common Parametric Aircraft Configuration Schema) Framework:

- Open-source platform for aircraft design data integration.
- Includes modules for fuselage, engine, wings, and cabin design.

### ➤ Integration Step:

- **Cabin Components:** Define and use templates for galleys, lavatories, seats, etc.
- **Data Integration:** Calculate cabin mass and center of gravity; integrate data for positions and mass.

### ➤ Other Key Components:

- Incorporate cabin data into CPACS.xml
- Generate comprehensive aircraft design

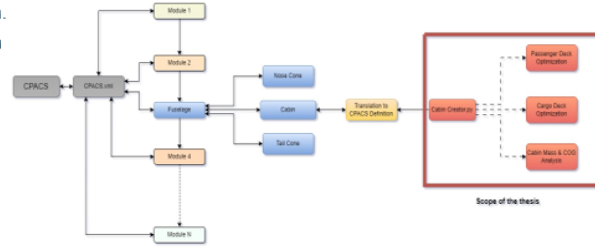


Figure 3 - The integrated CPACS and Python workflow

## Cargo Deck Optimization Workflow

### ➤ Optimization Tool Features:

- **Cargo Model Selection:** Choose from standard models; adapts to airline needs and conditions.
- **Automatic Optimization:** Maximizes space utilization; ensures safety and regulatory compliance.

### ➤ Algorithm Overview:

- **Input Analysis:** Assesses cabin and cargo dimensions; supports single and double deck setups.
- **Strategic Placement:** Iteratively places cargo while avoiding key components; adjusts based on cabin length and weight distribution.

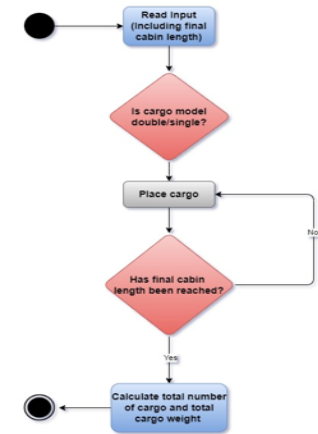


Figure 4 - Flow chart of the detailed explanation of cargo compartment design

## Passenger Deck Optimization Workflow

### ➤ Optimization Tool Features:

- **Input Requirements:** Details on flight class, seat configurations, and pitch; selects seat models and flight range.
- **Automatic Optimization:** Calculates cabin width, lavatory needs, and aisle widths for compliance.

### ➤ Algorithm Overview:

- **Initial Setup:** Uses flight range and passenger count to predict layout; places seats, lavatories, galleys, and exits.
- **Iterative Optimization:** Adjusts for fuselage length and regulations; ensures optimal seating and amenities.

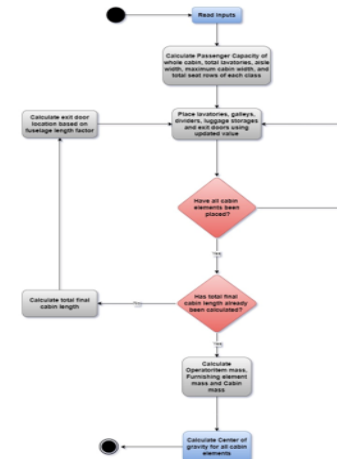


Figure 5 - Passenger Compartment Design Workflow

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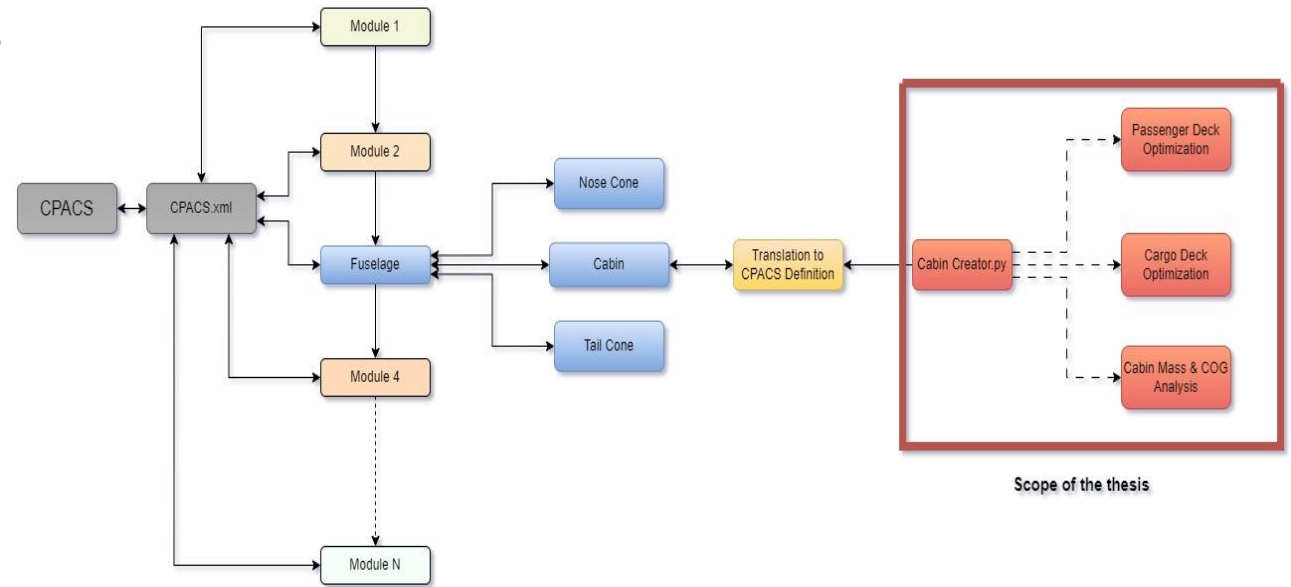


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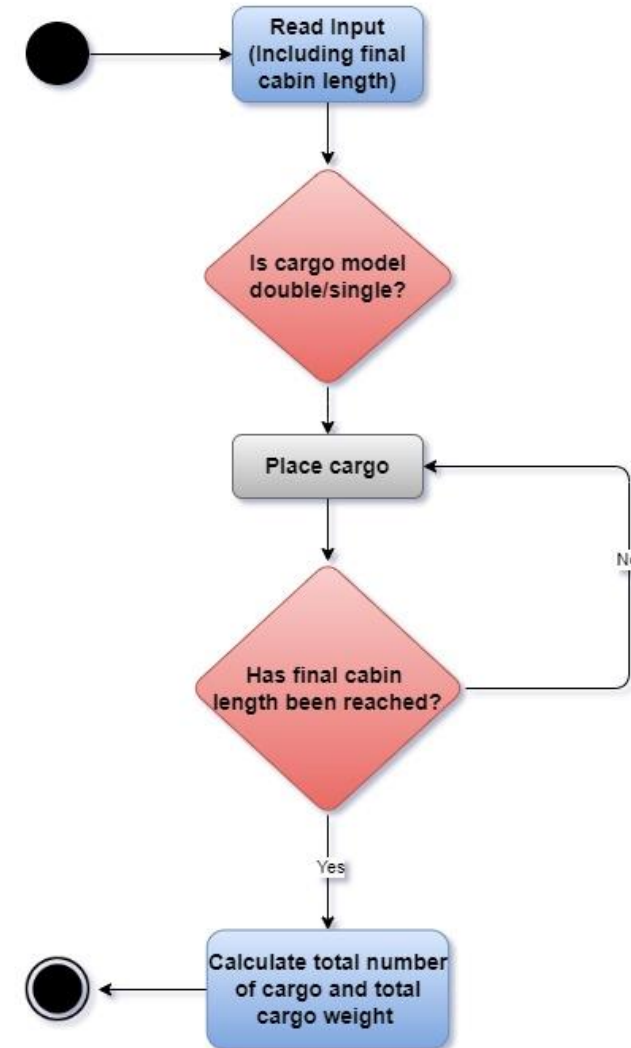


Figure 4 - Flow chat of the detailed explanation of cargo compartment design



# Passenger Deck Optimization Workflow

## ► Optimization Tool Features:

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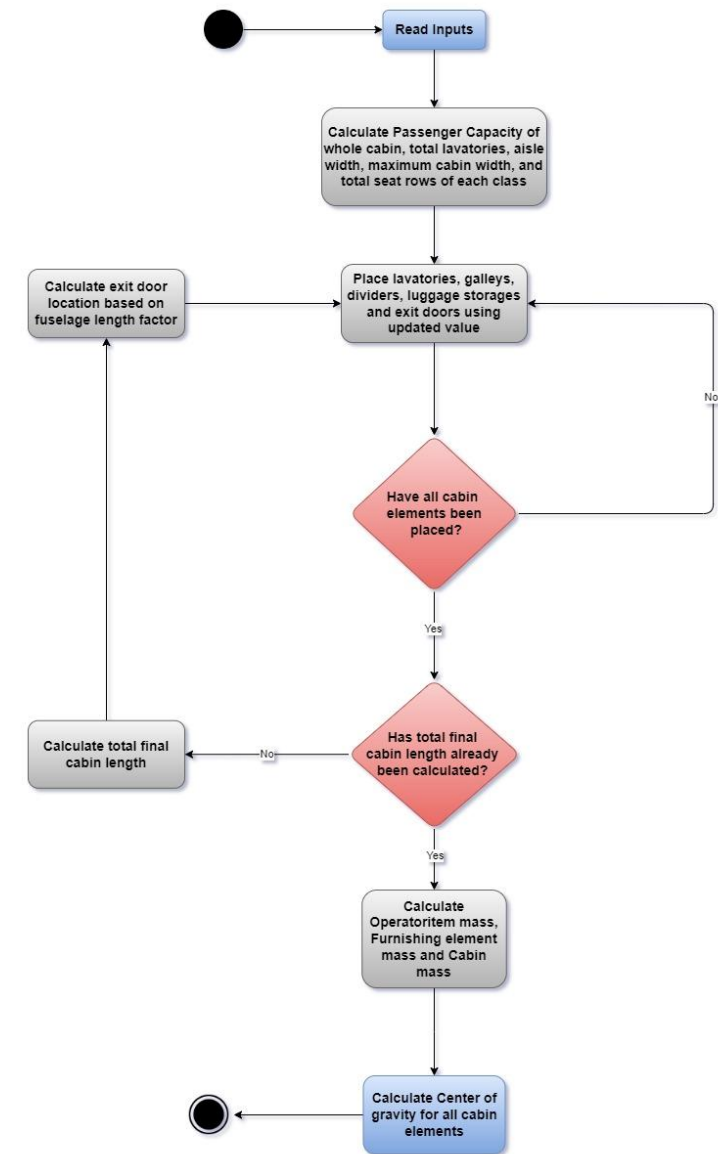


Figure 5 - Passenger Compartment Design Workflow

## Validation with Real World Cases

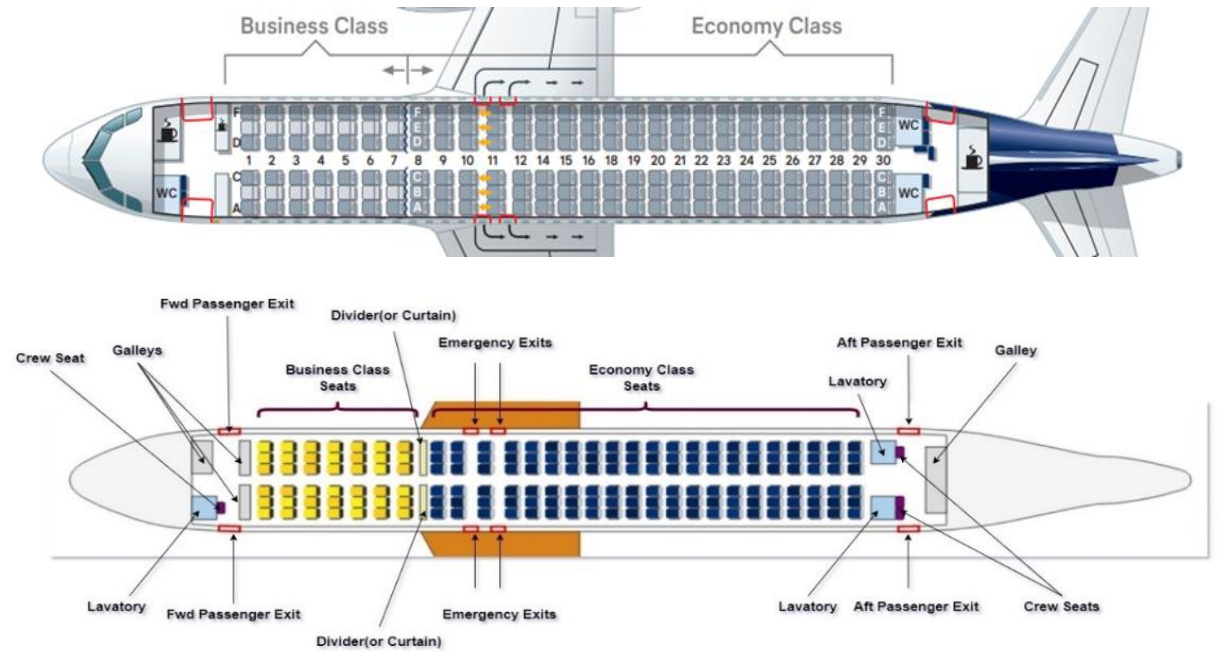


# Validation with Real-World Cases

## Airbus A320neo Validation:

Table 1: A320neo - Comparison between Calculated data and BHL internal data

A320neo		BHL data	Calculated	Differences
Total Number of Passengers	[-]	168	168	-
Business Class Passengers	[-]	42	42	-
Business Class Seat Pitch	[m]	0.8564	0.8564	-
Economy Class Passengers	[-]	126	126	-
Economy Class Seat Pitch	[m]	0.7422	0.7422	-
Cabin Length	[m]	27.57	27.76	0.6%
Cabin Width	[m]	3.70	3.67	0.8%
Number of Lavatories	[-]	3	3	-
Galley area	[m <sup>2</sup> ]	4.36	4.08	6.4%
Operator items	[kg]	-	3819.564	
Furnishing	[kg]	-	3109.14	
Total mass (Furnishing + Operator items)	[kg]	6944.0	6928.703	0.2%

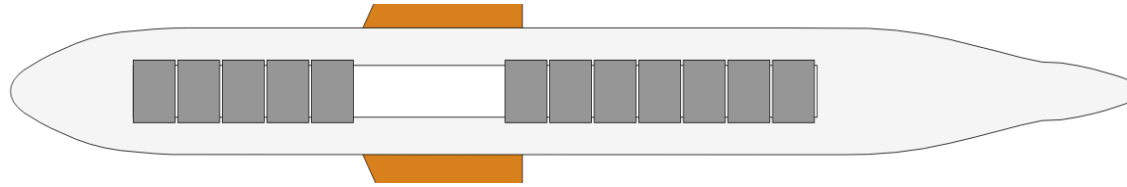


a) Top View

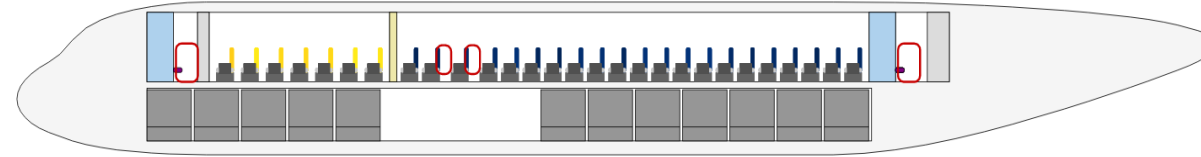
Figure 6(a) - Cabin layout of the Airbus A320neo generated using the tool

# Validation with Real-World Cases

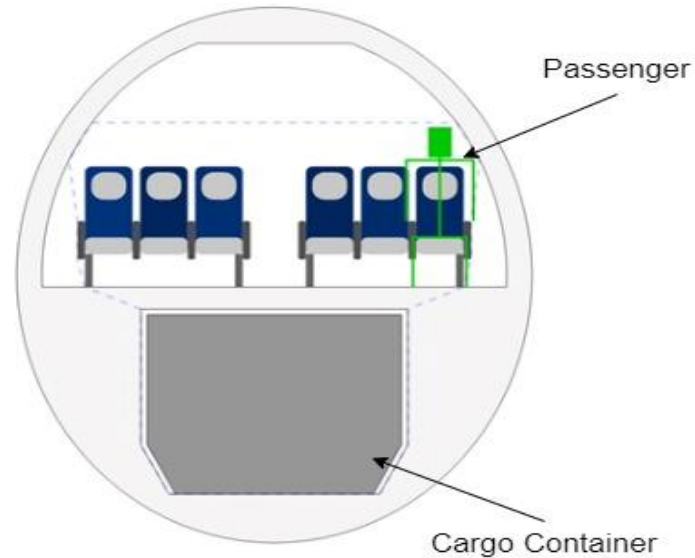
## Airbus A320neo Validation:



b) Bottom View



c) Side View



d) Main Cross Section View

Figure 6 - Cabin layout of the Airbus A320neo generated using the tool

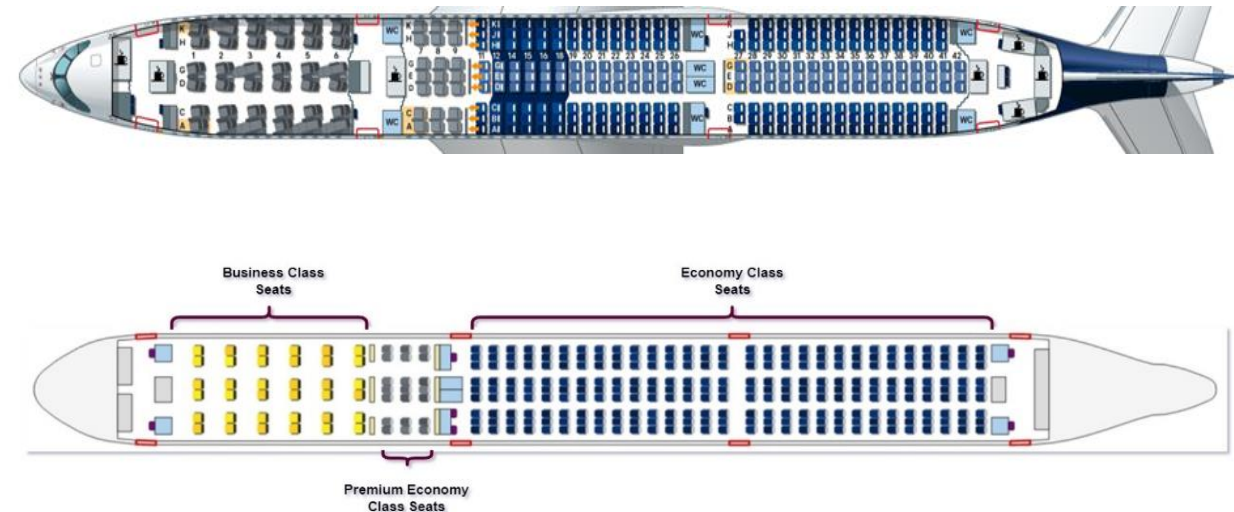
# Validation with Real-World Cases

## Airbus A350-900 Validation:

Table 2: A350-900 - Comparison between Calculated data and BHL internal data

A350-900		BHL data	Calculated	Differences
Total Number of Passengers	[-]	319	318	-
Business Class Passengers	[-]	36	36	-
Business Class Seat Pitch	[m]	1.732	1.732	-
Premium Economy Class Passengers	[-]	21	21	
Premium Economy Class Seat Pitch	[m]	1	1	
Economy Class Passengers	[-]	262	261	-
Economy Class Seat Pitch	[m]	0.95	0.95	-
Cabin Length	[m]	52.85	50.06	5.2%
Cabin Width	[m]	5.61	5.61	0%
Number of Lavatories	[-]	8	8	-
Galley area	[m <sup>2</sup> ]	7.81	8.70	11.39%
Operator items	[kg]	-	7690.931	
Furnishing	[kg]	-	8641.511	
Total mass (Furnishing + Operator items)	[kg]	23011.0*	16332.44	29.02%

\* - Obtained mass from BHL is old and needs to be updated



a) Top View

Figure 7(a) - Cabin layout of the Airbus A350-900 generated using the tool

# Validation with Real-World Cases

## Airbus A350-900 Validation:

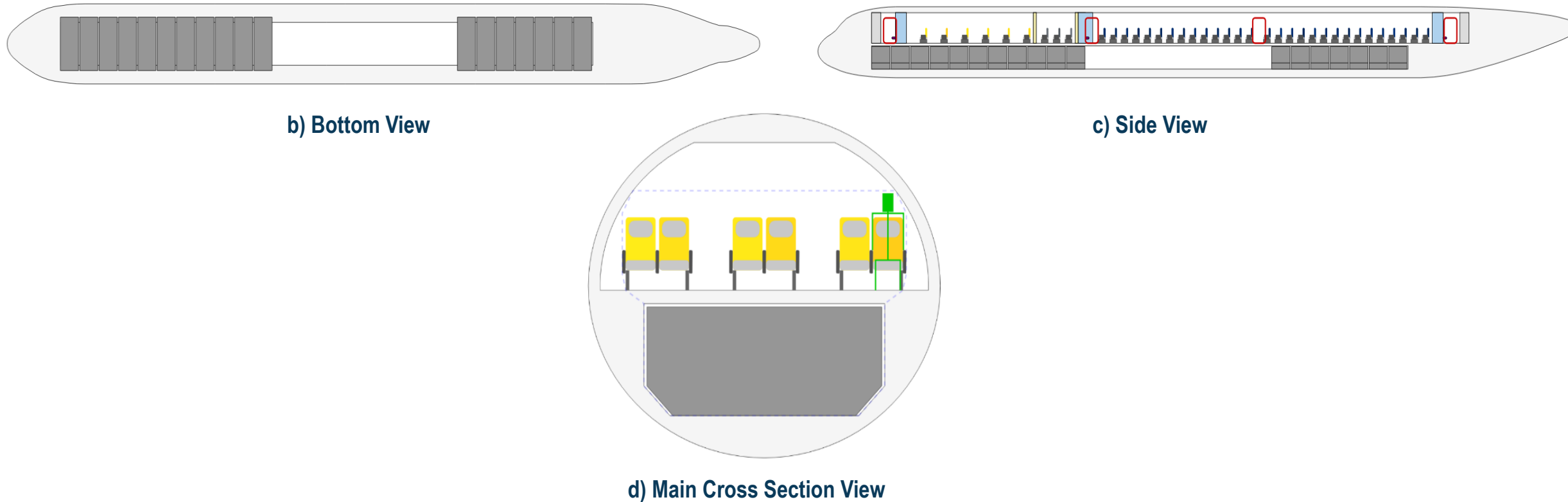


Figure 7 - Cabin layout of the Airbus A350-900 generated using the tool

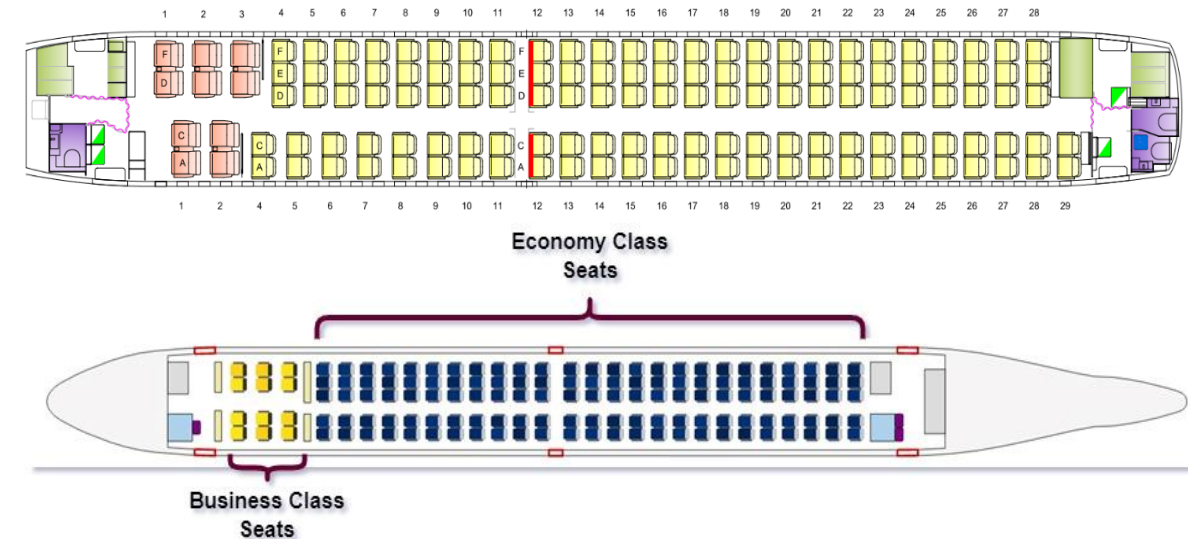


# Validation with Real-World Cases

## Airbus A220-300 Validation:

Table 3: A220-300 - Comparison between Calculated data and BHL internal data

A220-300		BHL data	Calculated	Differences
Total Number of Passengers	[-]	137	137	-
Business Class Passengers	[-]	10	12	-
Business Class Seat Pitch	[m]	0.9398	0.9398	-
Economy Class Passengers	[-]	127	125	-
Economy Class Seat Pitch	[m]	0.8128	0.8128	-
Cabin Length	[m]	27.5	28.92	5.1%
Cabin Width	[m]	3.28	3.24	1.2%
Number of Lavatories	[-]	2	2	-
Galley area	[m <sup>2</sup> ]	3.65	3.28	10.13%
Operator items	[kg]	-	3104.993	
Furnishing	[kg]	-	2985.2	
Total mass (Furnishing + Operator items)	[kg]	6036.9	6090.193	0.8%



a) Top View

Figure 8(a) - Cabin layout of the Airbus A220-300 generated using the tool

# Validation with Real-World Cases

## Airbus A220-300 Validation:

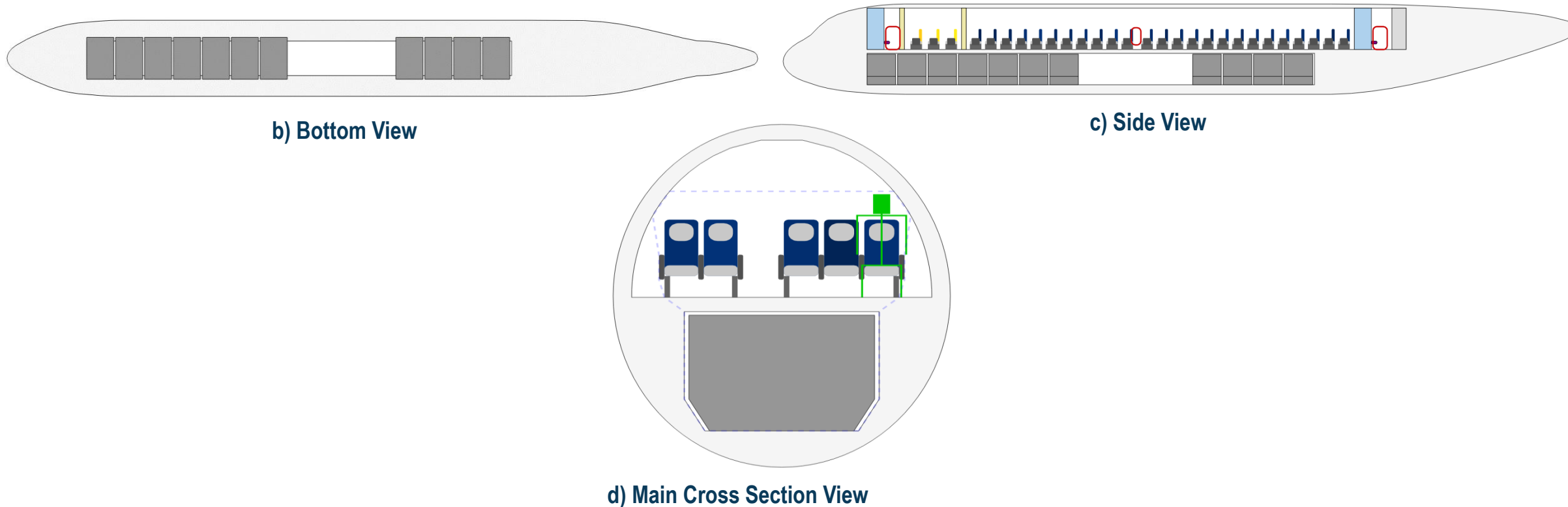


Figure 8 - Cabin layout of the Airbus A220-300 generated using the tool

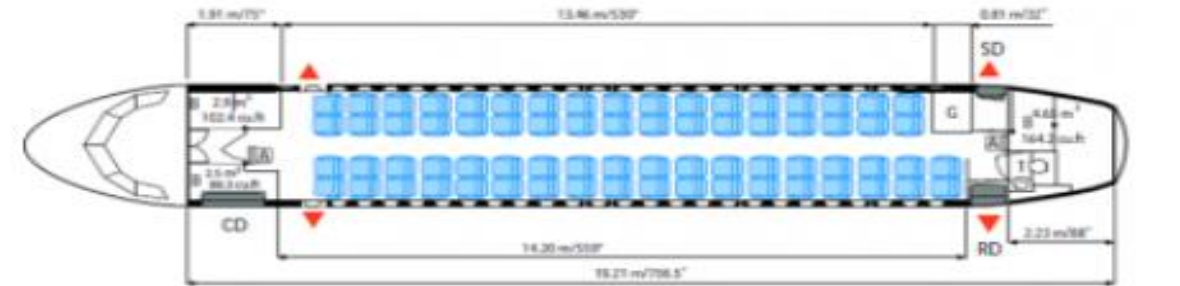
# Validation with Real-World Cases

## ATR72 Validation:

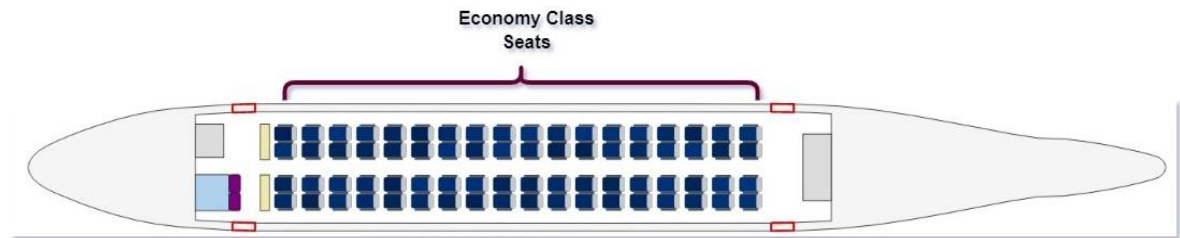
Table 4: ATR72 - Comparison between Calculated data and BHL internal data

ATR72		BHL data	Calculated	Differences
Total Number of Passengers	[-]	70	72	-
Economy Class Passengers	[-]	70	72	-
Economy Class Seat Pitch	[m]	0.7366	0.7366	-
Cabin Length	[m]	17.95	17.13	4.5%
Cabin Width	[m]	2.57	2.83	10.11%
Number of Lavatories	[-]	1	1	-
Galley area	[m <sup>2</sup> ]	2.16	1.94 m <sup>2</sup>	10.1%
Operator items	[kg]	-	1769.455	
Furnishing	[kg]	-	1288.541	
Total mass (Furnishing + Operator items)	[kg]	2324*	3057.996	31.58%

\* - Obtained mass from BHL is old and needs to be updated



Airlines Fleet TP ATR 72 seat chart c/o Airline Fleets

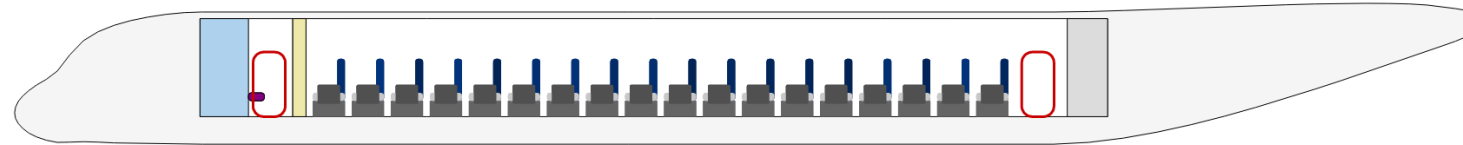


a) Top View

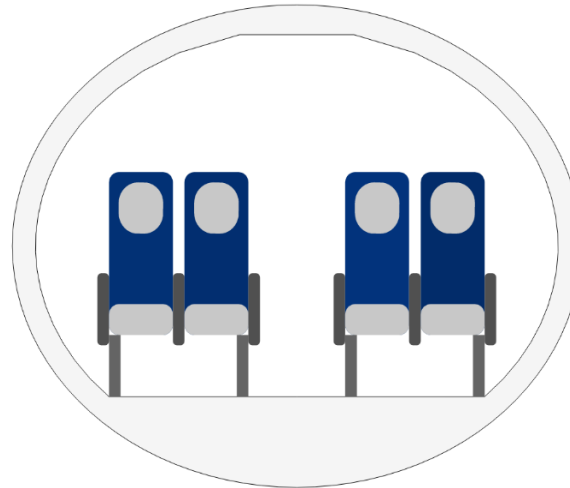
Figure 9(a) - Cabin layout of the ATR72 generated using the tool

# Validation with Real-World Cases

## ATR72 Validation:



c) Side View



d) Main Cross Section View

Figure 9 - Cabin layout of the ATR72 generated using the tool

# Validation with Real-World Cases

## Airbus A380-800 Validation:

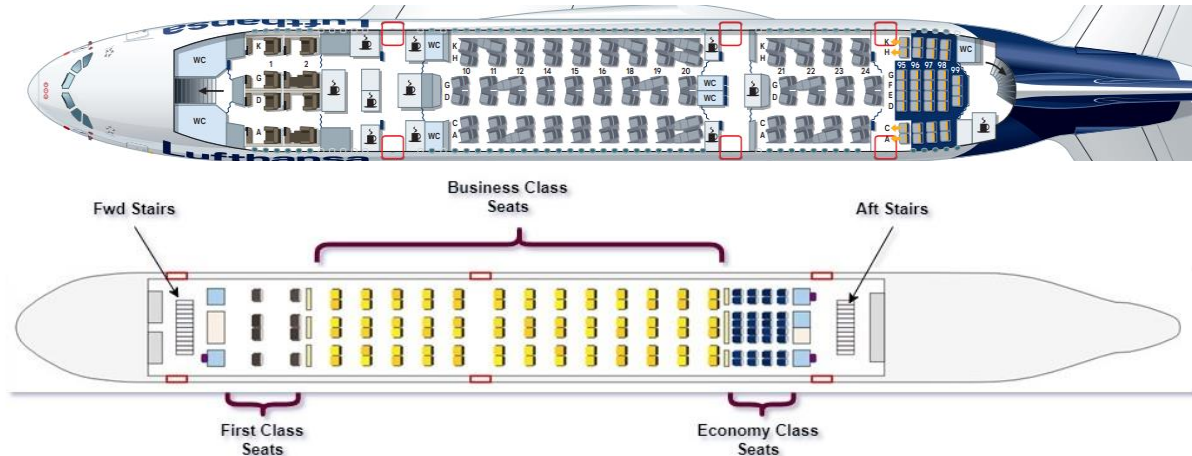


Figure 10(a) - Airbus A380-800 cabin layout: Upper Deck using the tool

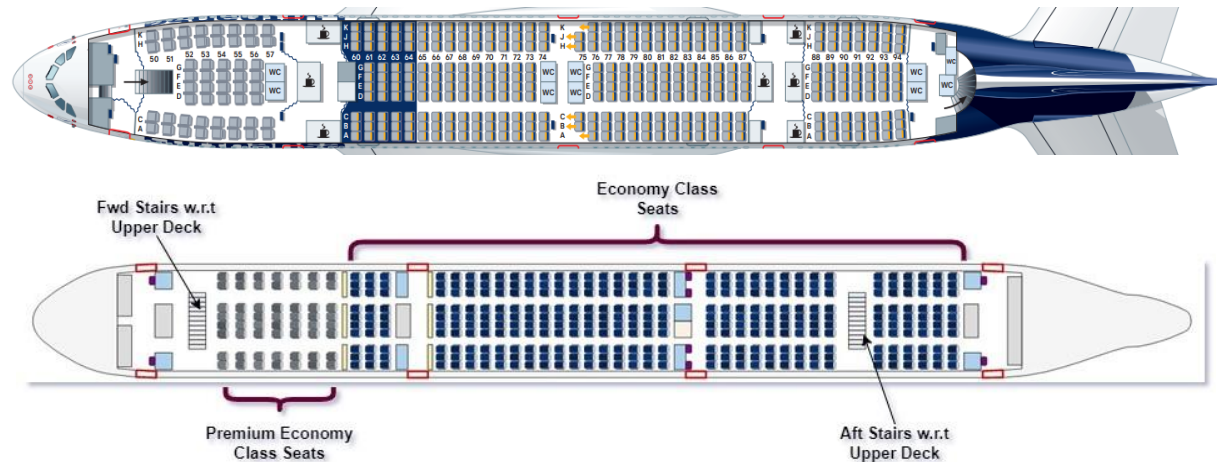


Figure 10(b) - Airbus A380-800 cabin layout: Main Deck using the tool

Table 5: A380-800 - Comparison between Calculated data and BHL internal data

A380-800		BHL data	Calculated	Differences
Upper Deck				
Total Number of Passenger	[-]	121	118	-
First Class Passengers	[-]	8	8	-
First Class seat pitch	[m]	2.05	2.05	-
Business Class Passengers	[-]	78	78	-
Business Class Seat Pitch	[m]	1.626	1.626	-
Economy Class Passengers	[-]	35	32	-
Economy Class Seat Pitch	[m]	0.7874	0.7874	-
Cabin Length	[m]	44.93	39.07	13.04%
Cabin Width	[m]	5.8	5.35	7.75%
Number of Lavatories	[-]	5	5	-
Galley area	[m <sup>2</sup> ]	-	5.65	-
Operator items	[kg]	-	3822.989	-
Furnishing	[kg]	-	4538.302	-
Main Deck				
Total Number of Passenger	[-]	388	396	-
Premium Economy Class Passengers	[-]	52	56	-
Premium Economy Class Seat Pitch	[m]	0.9652	0.9652	-
Economy Class Passengers	[-]	336	340	-
Economy Class Seat Pitch	[m]	0.7874	0.7874	-
Cabin Length	[m]	49.9	48.26	3.28%
Cabin Width	[m]	6.5	5.66	12.9%
Number of Lavatories	[-]	10	9	-
Galley area	[m <sup>2</sup> ]	-	11.52	-
Operator items	[kg]	-	11385.569	-
Furnishing	[kg]	-	8469.657	-
Total mass (Furnishing + Operator items)	[kg]	-	28216.517	-

# Validation with Real-World Cases

## Airbus A380-800 Validation:

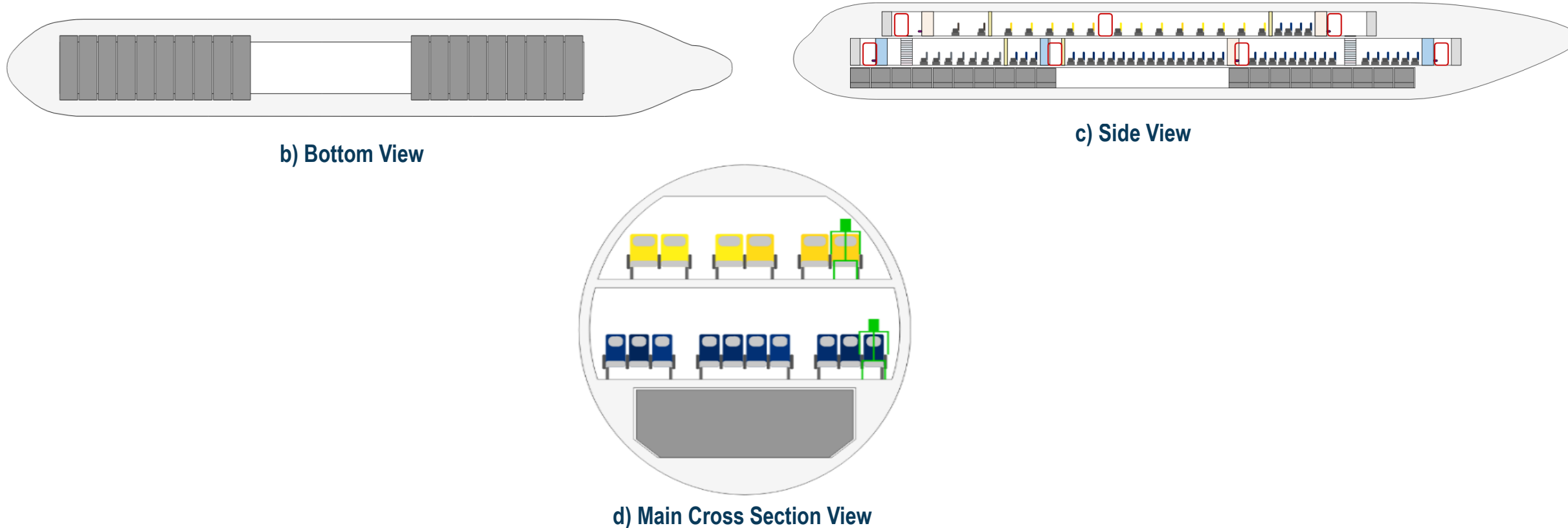


Figure 10 - Cabin layout of the Airbus A220-300 generated using the tool



## Flexibility and Application of the Design Tool



# Flexibility and Application of the Design Tool

## ► Non-Standard Seat Configurations:

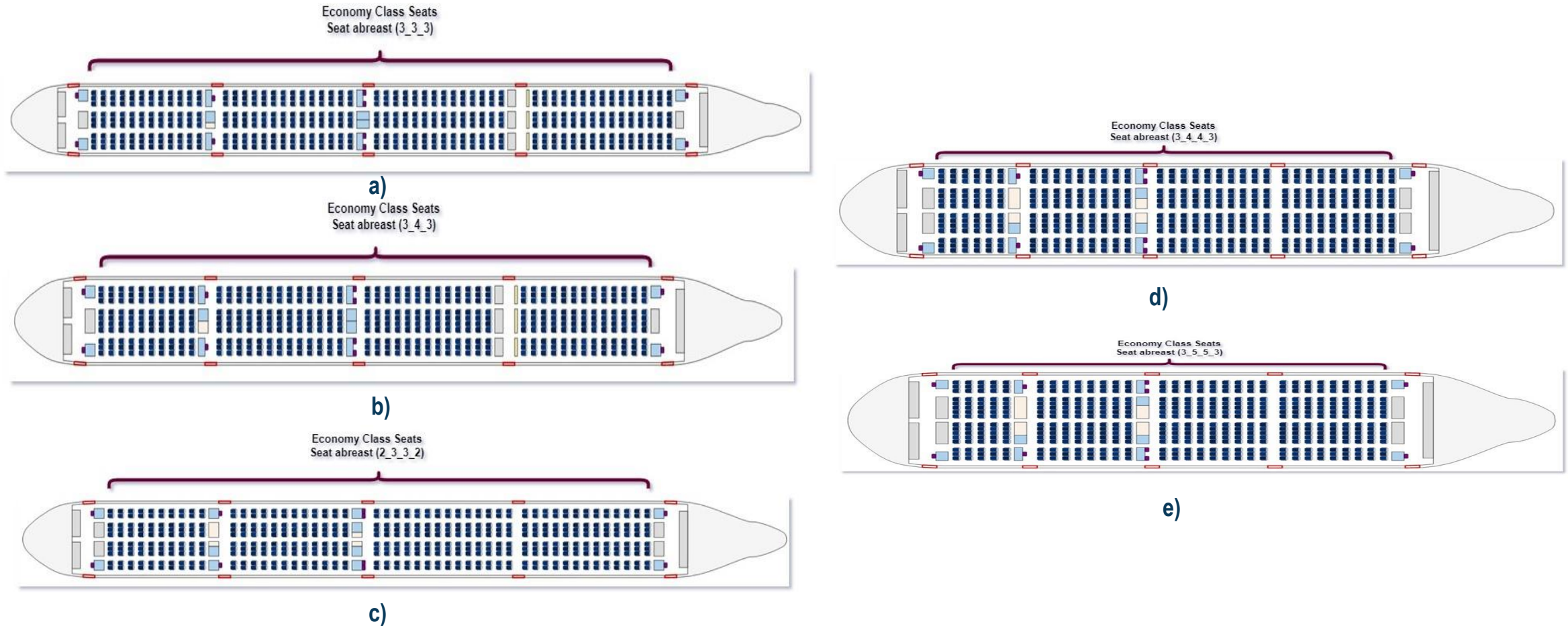


Figure 11 - Various Seat Configurations for the Same Number of Passengers



# Flexibility and Application of the Design Tool

## ► Multiple seats abreast in same class type:

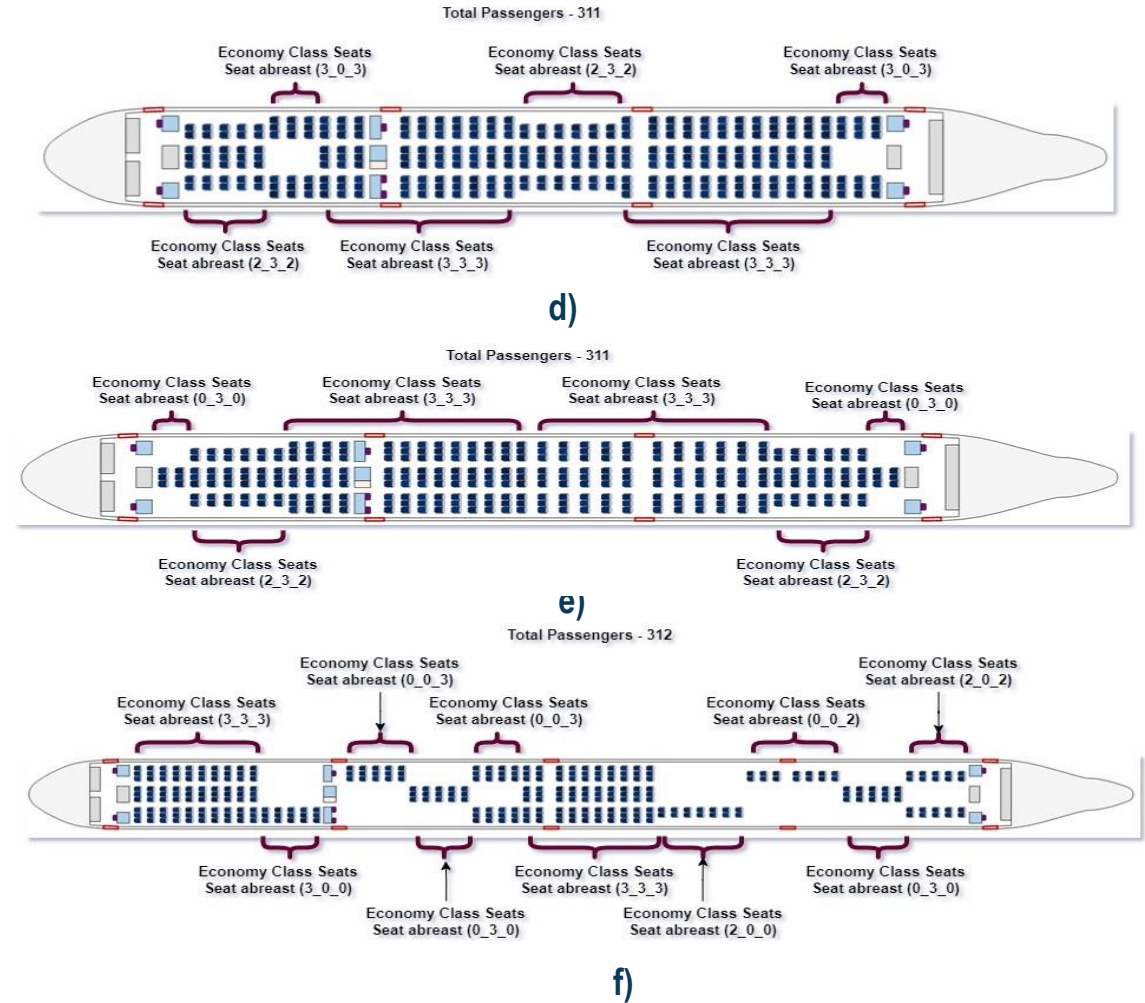
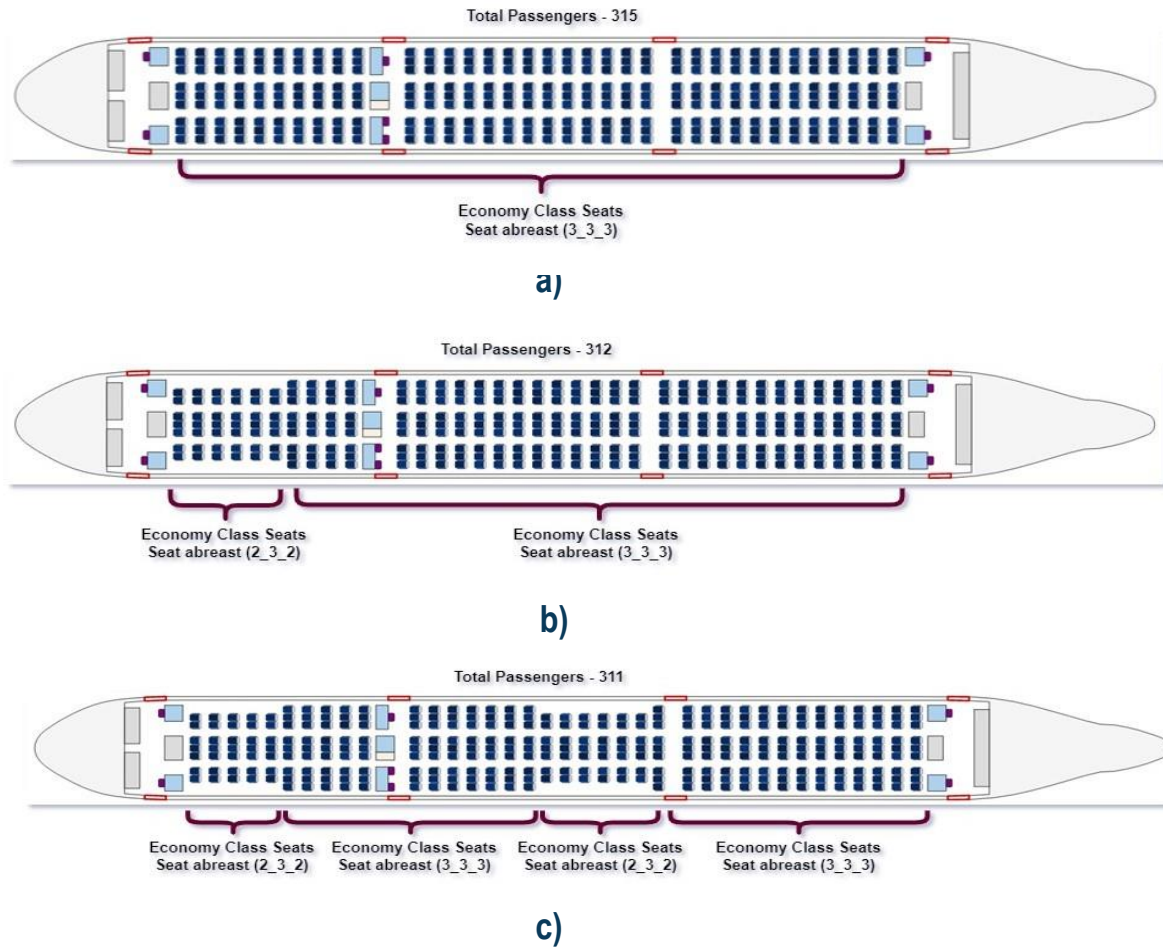


Figure 12 - Various Seat Configurations for the Same Number of Passengers

# Flexibility and Application of the Design Tool

## ► Multiple classes:

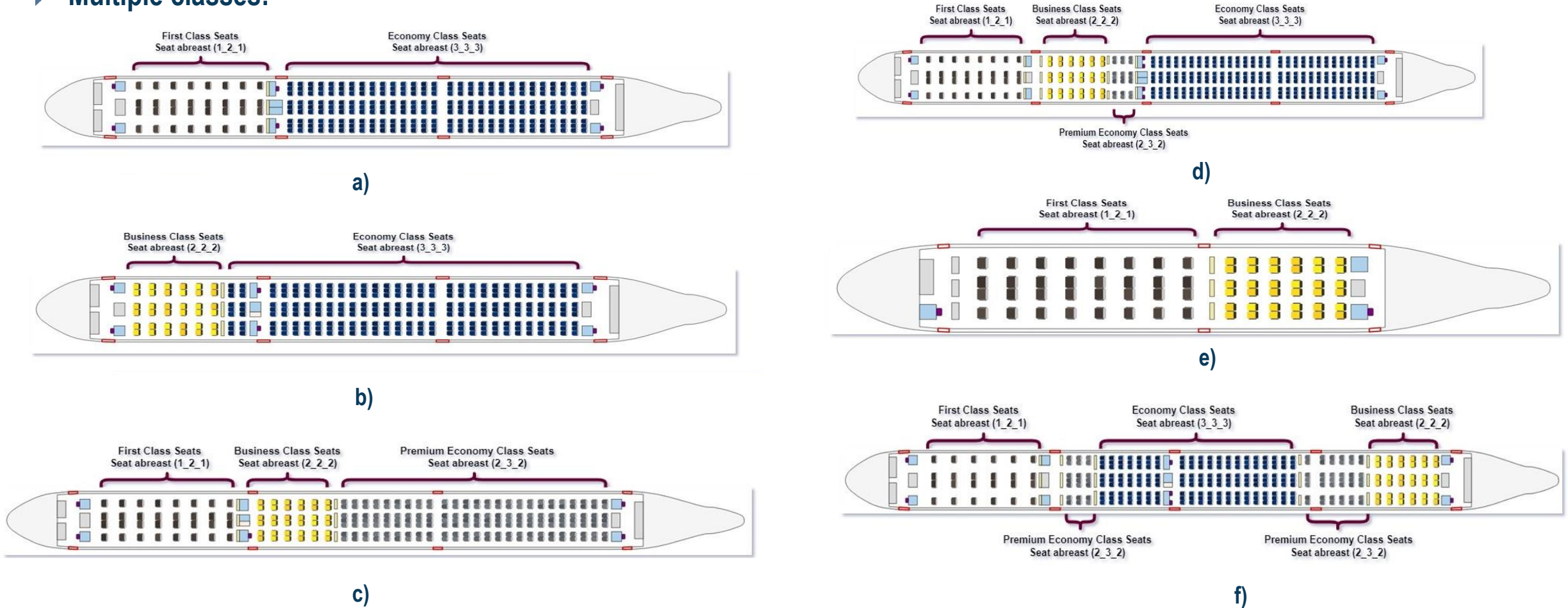


Figure 13 - Diverse Passenger Class Configurations Within a Single Cabin

# Flexibility and Application of the Design Tool

## ► Cargo Deck :

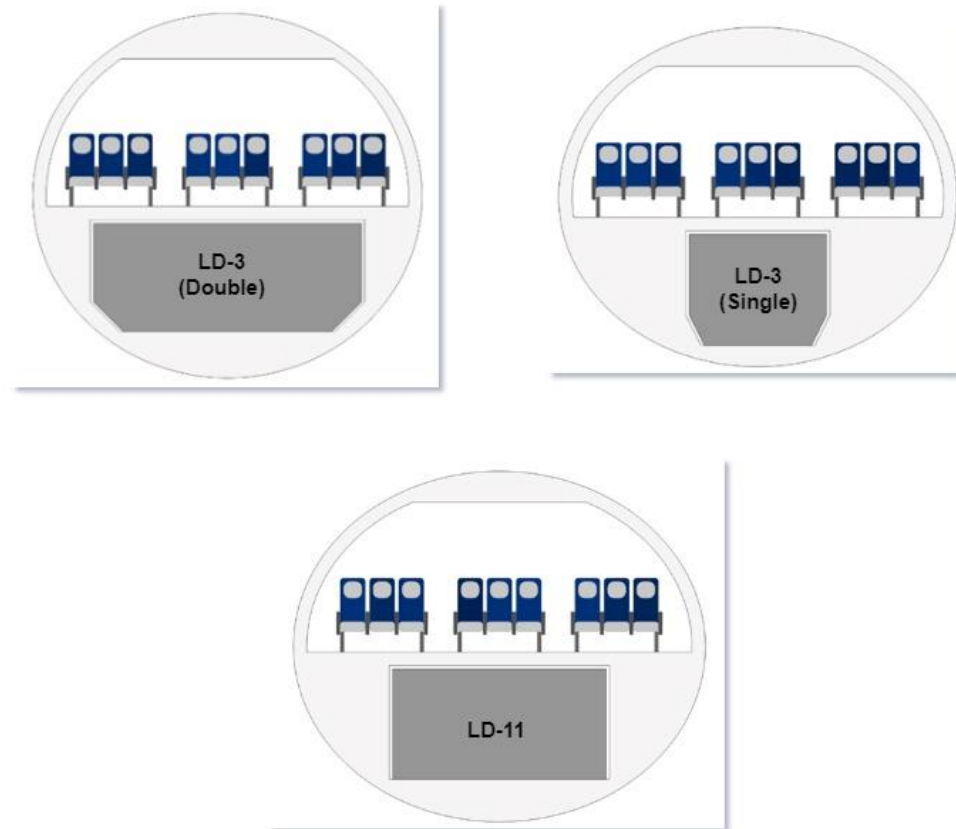


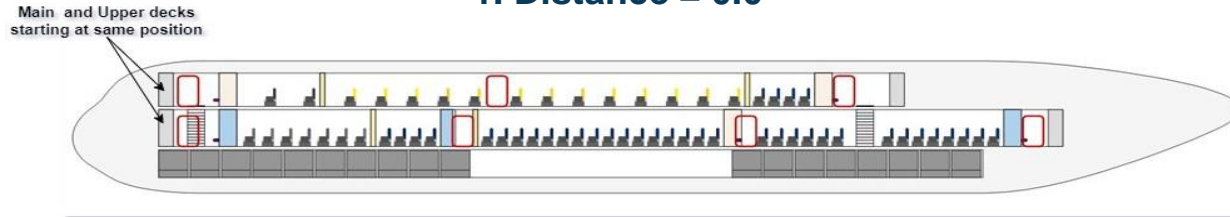
Figure 14 - Influence of Cargo Types on Aircraft Design



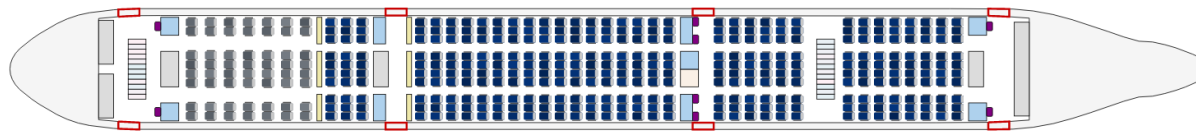
# Flexibility and Application of the Design Tool

## ► Upper Deck Placement:

1. Distance = 0.0



a) Side view

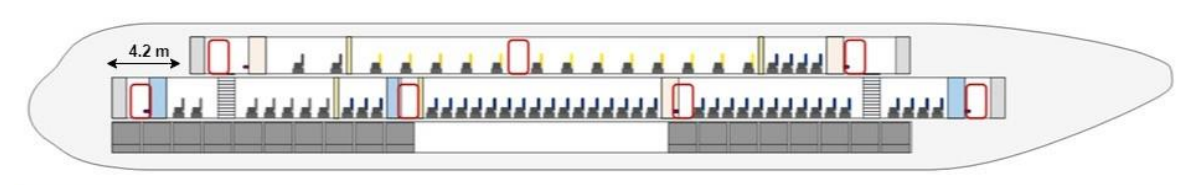


b) Top View of Main Deck



c) Top View of Upper Deck

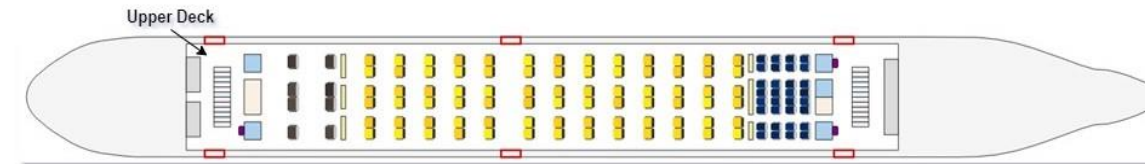
1. Distance = 4.2



a) Side view



b) Top View of Main Deck



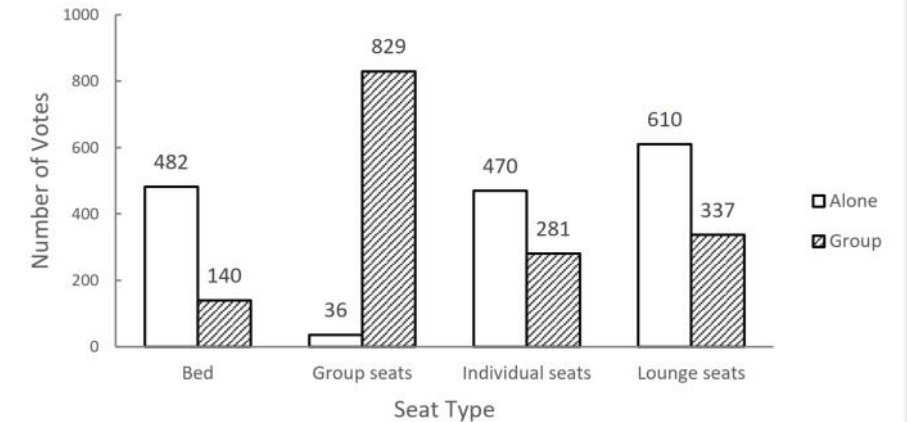
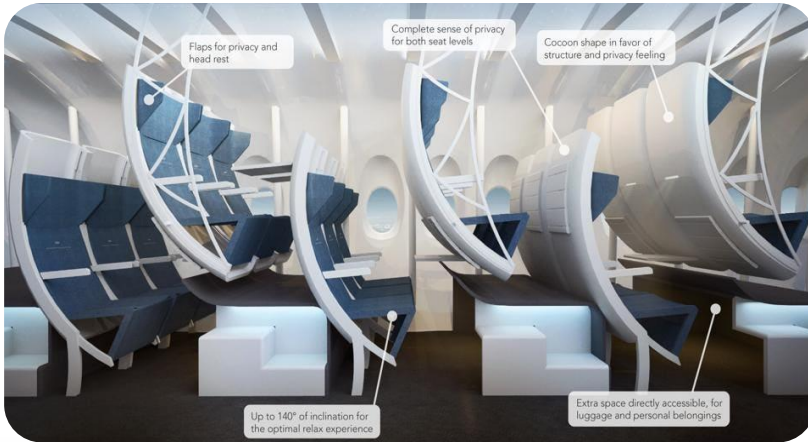
c) Top View of Upper Deck

Figure 15 - Effects of Upper Deck Starting Points on Cabin Layout and Stair Configuration

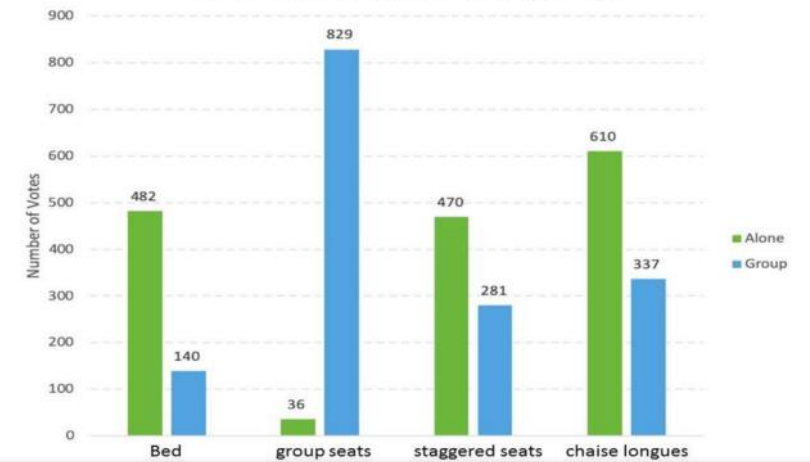


# Flexibility and Application of the Design Tool

## ► Unconventional Cabin Layout



Votes for Flying V at KLM Experience Days



# Flexibility and Application of the Design Tool

## ► Unconventional Cabin Layout: Sleeper Class

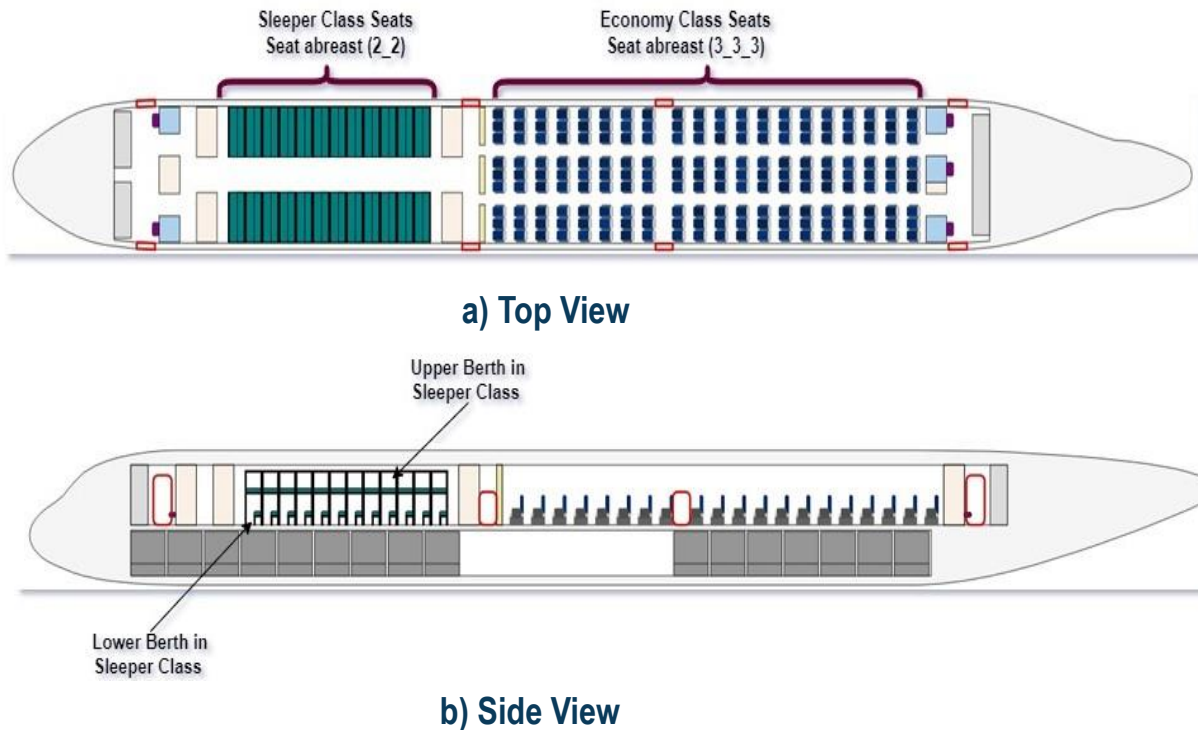


Figure 16 - Single-Aisle Sleeper Class Configuration Generated by the Tool

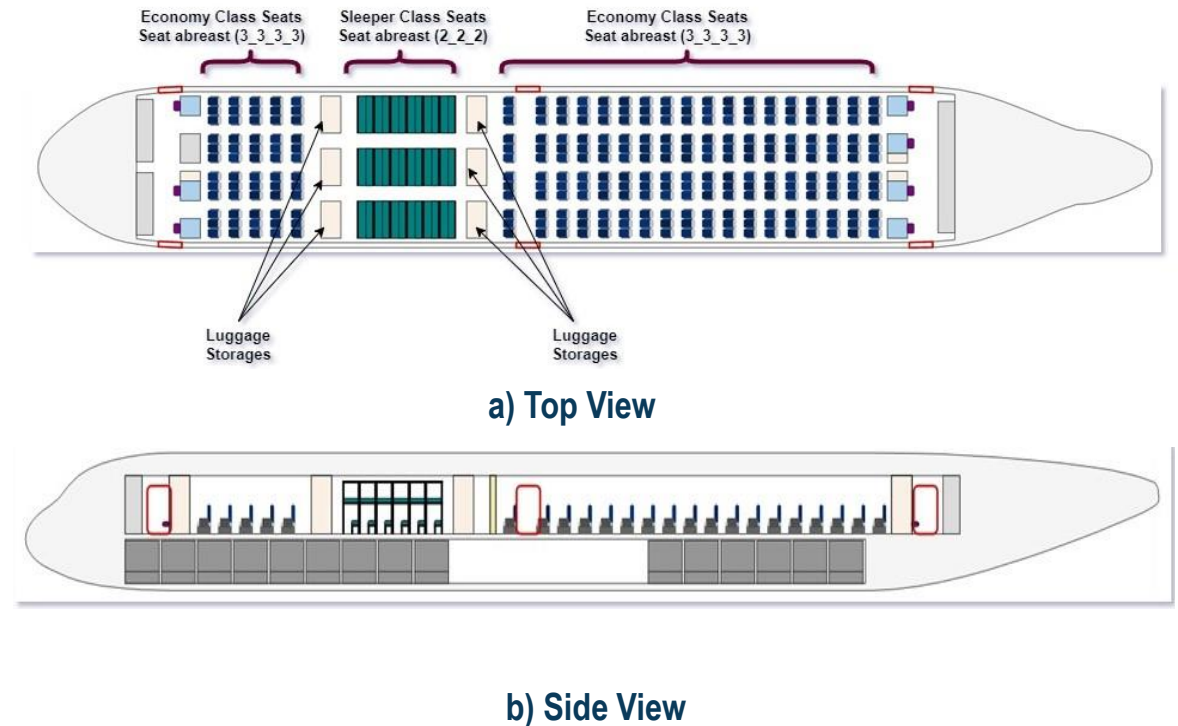
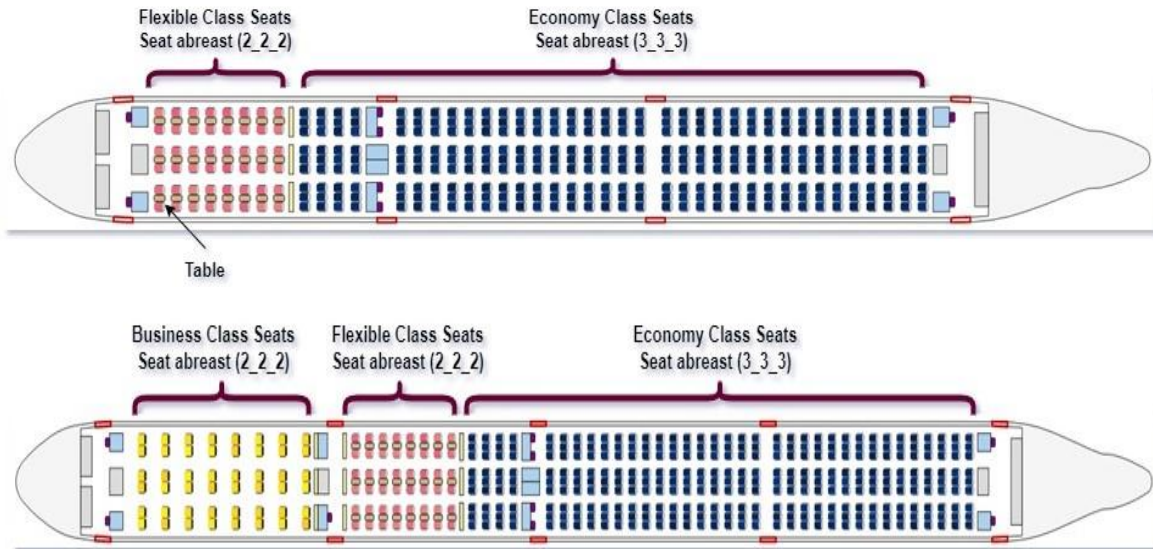


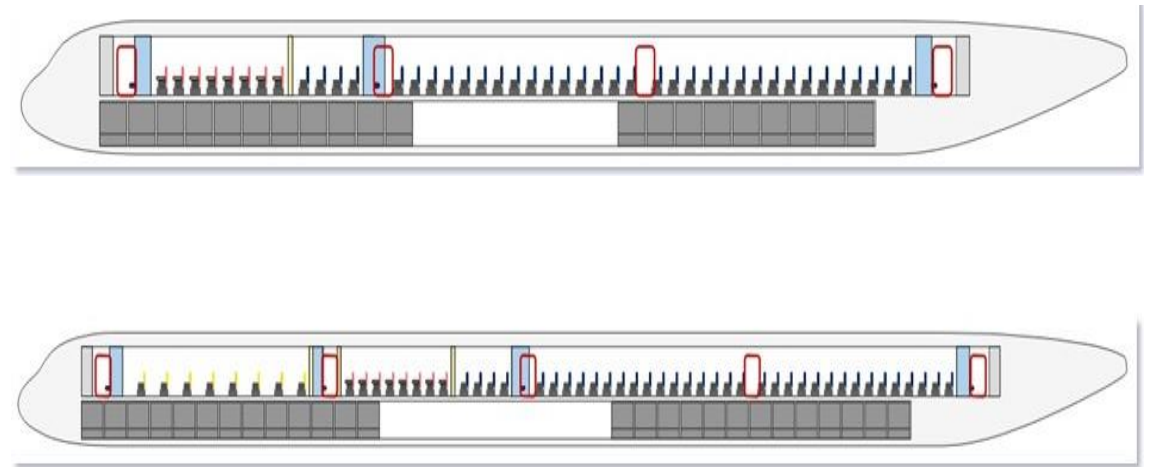
Figure 17 - Twin-Aisle Sleeper Class Configuration Generated by the Tool

# Flexibility and Application of the Design Tool

## ► Unconventional Cabin Layout: Flexible Class



a) Top View



b) Side View

Figure 18 - Flexible Class Configuration generated by the tool



# Flexibility and Application of the Design Tool

## ► Unconventional Cabin Layout: Group Class

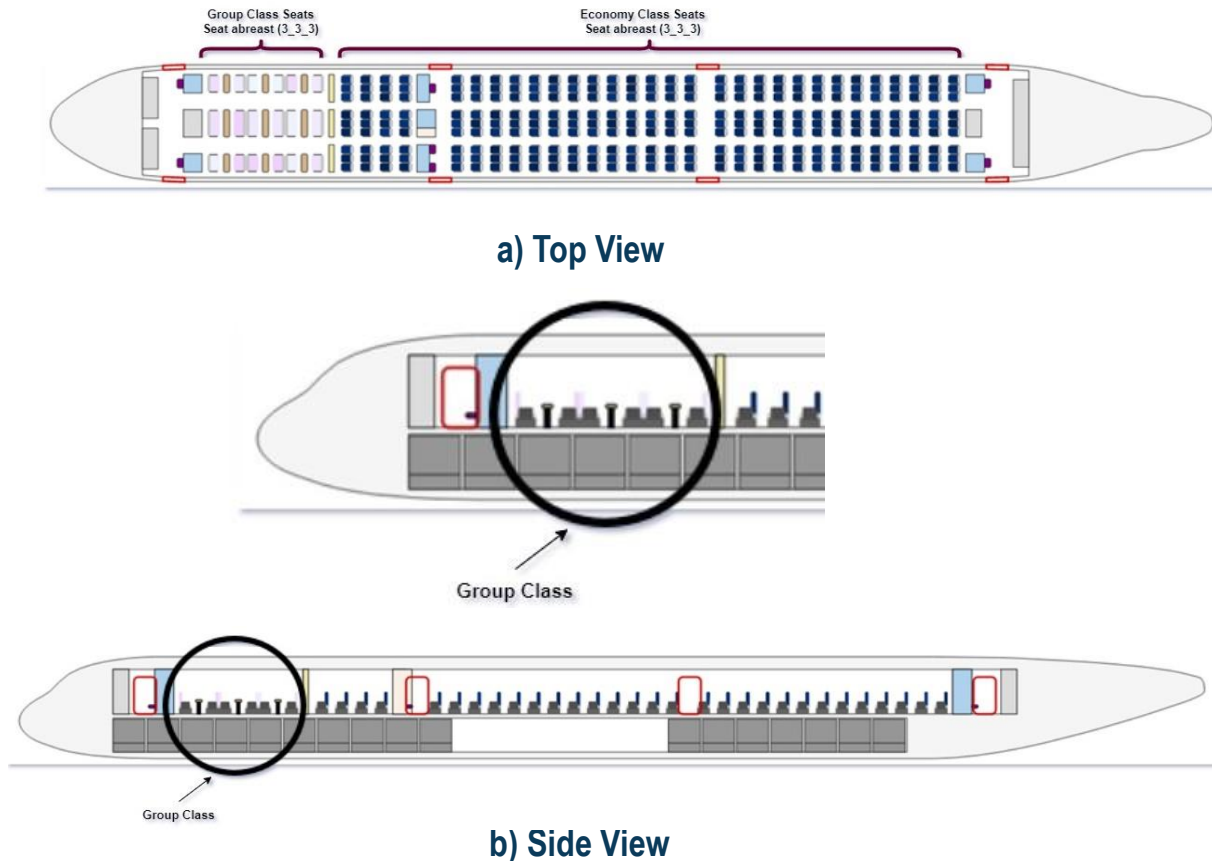


Figure 19 - Group Class Configuration generated by the tool

## ► Conventional and Unconventional Cabin Classes:

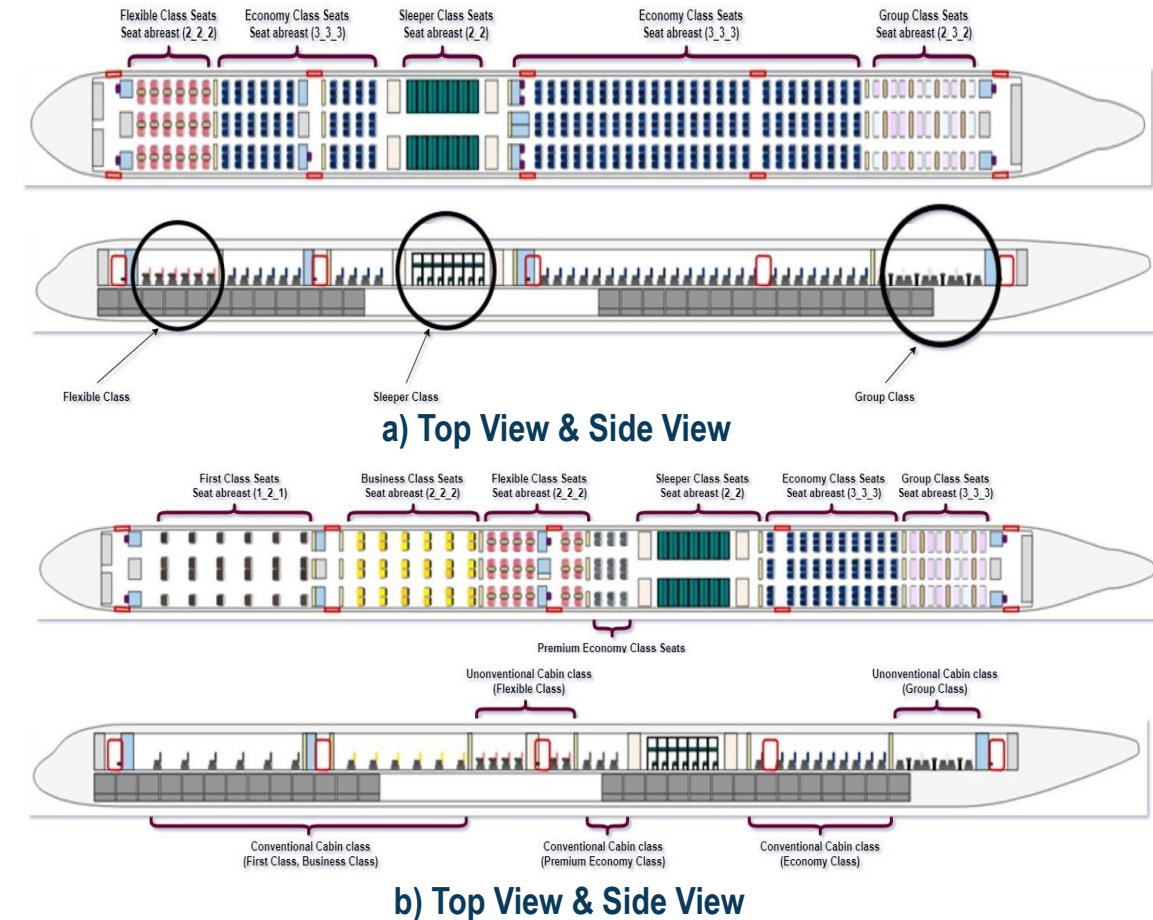


Figure 20 - Conventional and Unconventional Cabin Classes

# Conclusion

## Content:

### ➤ Objective:

- **Tool Development:** Bridge the gap between cabin and fuselage design with versatile options and minimal input.

### ➤ Validation:

- **Models Analyzed:** A320neo, A350-900, A220-300, ATR72, A380-800.
- **Accuracy:** High precision in layout and mass estimation.

### ➤ Key Results:

- **Length Variance:** Max ~5%.
- **A320neo:** 0.2% mass variance; highest accuracy.

### ➤ Comparison with Existing Tools:

- **PreSTo:** Excel-based; limited to conventional designs. ✓
- **ParaFuse:** Limited to standard layouts. ✓

### ➤ Tool Features:

- **Configuration Flexibility:** Supports non-standard seats and diverse layouts.
- **Regulatory Compliance:** Adheres to EASA standards for unconventional designs.

Table 6: Validation Data

Model	BHL data	Calculated Length	Difference	BHL data	Calculated Mass	Difference
A320neo	27.57	27.76	0.6%	6944	6928.703	0.2%
A350-900	52.85	50.06	5.2%	23011*	16332.44	29.02%
A220-300	27.5	28.92	5.1%	6036.9	6090.193	0.8%
ATR-72	17.95	17.13	4.5%	2324*	3550.812	31.5%
A380-800 (Upper Deck)	44.93**	39.07	13.04%		8427.627	-
A380-800 (Main Deck)	49.9	48.26	3.28%		19877.273	-

\* - Obtained mass from BHL is old and needs to be updated

\*\* - Original Cabin length is longer due to excess galley structures

# Future Scope

## Content:

### ➤ Enhancements:

- **Seat Capacity:** Increase seats abreast to meet future demand.
- **Seating Layouts:** Explore unconventional arrangements.
- **Lavatory Capacity:** Expand beyond 12 per deck..

### ➤ Realistic Designs:

- **Lavatories/Galleys:** Update designs for realism.
- **Stair Integration:** Include varied designs for flexibility

### ➤ Additional Features:

- **Cross-Section Shapes:** Introduce diverse shapes.
- **Door Placement:** Enable flexible, EASA-compliant placements.
- **Overhead Bins:** Design for comprehensive layouts.

### ➤ Weight Estimation:

- **Update Methods:** Revise Torenbreek's methods with current data.
- **Calibration Factor:** Include adjustments for modern materials.





**Thank You!**

**I appreciate your time and attention.**



# Detailed Mass and COG Analysis

Element	Sub element	Value [kg]
Operator items	Total Food Weight	718.07
	Total Crew Weight	503.52
	Total Emergency Equipment Weight	368.13
	Total Galley Weight	283.169
	Total Seats Weight	1548.4
	Total Divider Weight	6.825
	Total Door Weight	242.15
	Total miscellaneous Weight	149.3
Total Operator items Weight		3819.564
Furnishing	Total Overhead Bins Weight	665.11
	Total Crew Seat Weight	153.23
	Total Fresh (Portable) Water Weight	125.88
	Total Lavatory Weight	274.55
	Cabin Insulation Weight	197.57
	Cabin Lining Weight	604.2
	Floor Carpet Weight	187.118
	Cargo Deck Lining Weight	330
	Cargo Loading System Weight	332.06
	Cabin Lighting Weight	220.301
	General Weight	19.12
Total Furnishing Weight		3109.14
Total Mass (Operator items + Furnishing)		6928.703

Elements	Quantity	Total Weight	COG X [m] [w.r.t Deck]	COG Y [m] [w.r.t Deck]
Galley	4	283.169	13.979	0.22
Food	-	718.07	13.979	0.22
Lavatory	3	274.55	17.116	-0.366
Luggage Storages	-	-	-	-
Divider	2	6.825	8.52	0.0
Table	-	-	-	-
Staircase	-	-	-	-
Crew seat	4	153.23	19.806	-0.549
Bed	-	-	-	-
Seat	168	1548.4	13.889	0.0
Overhead Bin	-	665.11	13.889	0.0
Door	8	242.14	12.701	0.0
Fresh (Portable) water	1	125.88	8.25	0.0
Cargo	11	902	13.281	0.0
Emergency Equipment	168	368.13	13.822	0.0
Cabin Insulation	1	197.57	13.882	0.0
Cabin Lining	1	604.2	13.882	0.0
Floor Carpet	1	187.118	13.882	0.0
Cargo Deck Lining	1	330.0	10.902	0.0
Cargo Loading	1	332.06	10.902	0.0
Cabin Lighting	1	220.301	13.882	0.0
General	1	19.12	13.882	0.0
Total Cabin Elements		7177.883	13.225	0.005