



Hochschule für Angewandte Wissenschaften Hamburg
Hamburg University of Applied Sciences

Master Thesis

Studiendepartment Fahrzeugtechnik und Flugzeugbau

**Conceptual Design of Fuselages, Cabins and
Landing Gears – Methods, Statistics, Tool Setup**

Pieter-Jan Goderis

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Katholieke Hogeschool Brugge – Oostende
Departement Industriële Wetenschappen – Technologie
Campus Oostende
Zeedijk 101
B-8400 Oostende
Belgium

In cooperation with:

Hochschule für Angewandte Wissenschaften Hamburg
Departement Fahrzeugtechnik und Flugzeugbau
Berliner Tor 9
20099 Hamburg
Germany

Author: Goderis Pieter-Jan
Delivery date: 30. June 2008

1. Examiner: Prof. Dr.-Ing. Dieter Scholz
2. Examiner: Dipl.-Ing. Kolja Seeckt

Tutor: Dipl.-Ing. Kolja Seeckt

Abstract

The tool – in form of a Microsoft Excel sheet - is made for easily proposing input data for the preliminary aircraft design and the optimization of the program PrADO. By using several statistic data, empirical formulas and a minimal of input data, propositions of dimensions for airplane fuselages and landing gear are given.

The designing goal of this tool is conventual airplanes for commercial passenger use. For smaller bussiness jets the tool could be used too, but is not so reliable. The tool can be used for very large aircraft but is limited to single deck aircraft.

When used for very large aircraft this will result in a high amount of seats abreast and a lot of lost space in the cross-section, or a very long aircraft with an increased weight a passenger because of higher bending moments.

The landing gear part of the tool is based on a tricycle landing gear layout. Because of limited designing methods, only a limited amount of output can be given.

When the tool is compared to realty by use of some examples, there can be seen that the tool is quiet correct.



DEPARTMENT FAHRZEUGTECHNIK UND FLUGZEUGBAU

Conceptual Design of Fuselages, Cabins and Landing Gears – Methods, Statistics, Tool Setup

Task for a *Master Thesis* at KHBO

Background

This master thesis is part of the aircraft design research project “Green Freighter” (<http://GF.ProfScholz.de>). In this project the tool PrADO “Preliminary Aircraft Design and Optimization program” is used to investigate and optimize different aircraft configurations which requires an extensive input file.

Task

The student shall create a tool to support the conceptual design of aircraft fuselages, cabins and landing gears. Based on a minimum of input data, fuselages, cabins and landing gears shall be defined in as much detail as required in conceptual design. In addition, the generated data shall be available in a format that facilitates the generation of a PrADO input file. The thesis shall include

- the research of elements towards a conceptual design of aircraft fuselages, cabins and landing gears,
- the combination of the conceptual design elements with own statistics towards a comprehensive conceptual layout process for fuselages, cabins and landing gears,
- the programming of an easy-to-use tool for conceptual fuselage, cabin and landing gear design based on MS Excel,
- the programming of an interface to generate sections of the PrADO input file required for the definition of fuselages, cabins and landing gears.

This Master Thesis is related to a second Master Thesis “Conceptual Design of Wings and Tailplanes – Methods, Statistics, Tool Setup”. Both theses shall apply the same layout principles, programming styles and styles defined for the user interface.

The report has to be written according to German or international standards on report writing!

Declaration

This Thesis is entirely my own work. Where work has been used from others, it has totally been acknowledged and referenced.

June 30, 2008

Date

Signature

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Nomenclature

D	Diameter of a wheel
F	Allowable load of a multiple tire unit
k	Factor in value of F
l/d	Overall length to the effective diameter ratio
W_{main}	Weight on each wheel of the main landing gear

List of Abbreviations

ACN	Aircraft Classification Number
CS	Certification Specifications (for Aeroplanes)
FAR	Federal Aviation Regulations
HAW	Hochschule für Angewandte Wissenschaften Hamburg
IFL	Institut für Flugzeugbau und Leichtbau
MTOW	Maximum Take Off Weight
MTW	Maximum Taxi Weight
$N_{\text{cross aisles}}$	Number of cross aisles
N_{pax}	Number of passengers
$N_{\text{pax Row}}$	Number of passengers in a row
N_{sa}	Number of seats abreast
N_{toilets}	Number of toilets in the length
N_{galleys}	Number of galleys in the length
p	The seat pitch
PCN	Pavement Classification Number
PrADO	Preliminary Aircraft Design and Optimization
PreSTo	Preliminary Sizing Tool

Terms and definitions

Aircraft Classification Number

ACN or Aircraft Classification Number gives a classification code of an aircraft concerning the impact on the ground of an airfield

The ACN is two times the derived single wheel load plus an upgrade for the interference effects of the adjacent wheels. This interference is often left behind. (**Trahmer 2008**)

Cross aisles

The cross aisles are the aisles who are perpendicular on the main aisles and are going from there to the emergency exits.

Derived single wheel load

This is the static load on one wheel.

Pavement classification number (PCN)

This is the classification code of an airfields pavement concerning the load carrying capability.

Maximum Take-Off Weight (MTOW)

MTOW is the maximum weight at which the pilot of the aircraft is allowed to attempt to take off.

Maximum Taxi Weight (MTW)

MTW is the certified maximum allowable weight of the airplane when on the ground. This is the MTOW plus the fuel for taxiing and take-off.

Number of seats abreast (N_{sa})

This is the amount of passenger sitting next to each other, or the amount of seats seen in the cross-section.

Seat pitch

This is the length from the back of the seat until the next seat; the length needed for one seat in the airplane. See Figure 0.1

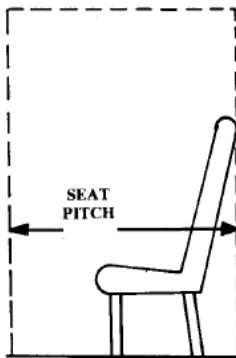


Figure 0.1 Seat pitch (Raymer 1989)

Slenderness ratio

The L/D or slenderness ratio is the overall length of the airplane divided by the effective diameter.

Stretching and shrinking of an aircraft

Stretching and shrinking of an aircraft is often done to react to changing market demands. Stretching an aircraft gives extra load carrying potential and improves the per-seat efficiency. Shrinking gives a longer range because of weight loss (fuselage cabin and payload).

With stretching and shrinking, the tail and nose are kept the same but cabin is stretched or shrunk. As can be seen in Figure 0.2

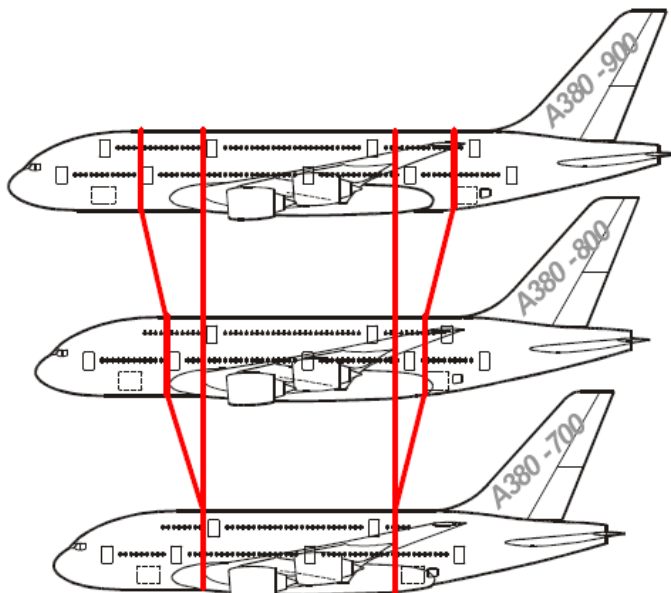


Figure 0.2 Stretching and shrinking of an aircraft (Trahmer 2008)

1 Introduction

1.1 Motivation

This Master thesis is done under the “Green Freighter” project. The goal for this project is to preliminary design conventional and unconventional aircraft; targeted on environment friendly aircraft. For preliminary sizing IFL’s PrADO is used. This program asks for an extensive input, to make it easier for the user to produce this input the development of a new program is started at the HAW that is called PreSTo, this program is based on Microsoft Excel.

This thesis contains making a part for this program concerning preliminary sizing of the cabin and fuselage layout; also the sizing of the landing gear has to be made; this all by using as less input as possible.

The spreadsheet of the fuselage is derived from the tool that Dipl.-Ing. Kolja Seeckt made.

1.2 Objectives

For this thesis a tool is made for conceptual designing of aircraft fuselages, cabins and landing gear- this should be as detailed as possible-; everything should be based on a minimum of input data. The tool has to be collided with the tool for preliminary designing wings, empennages and high lift systems made by colleague Coene, Steven and the tool for preliminary aircraft sizing made by Prof. Dr.-Ing. Dieter Scholz. The tool should also be easy to use for non-experts.

1.3 Literature Study

For the fuselage formulas I used (**Scholz 1999**) and (**Howe 2000**), for values I used (**Scholz 1999**) and (**Trahmer 2008**).

(**Howe 2000**) has innovating good statistical formulas while Roskam and the rest mostly have describing literature, also the values concerning sizes of seats, aisles and landing gear of (**Roskam III and IV 1989**) I consider to old to be used in newer aircraft. Values -when possible- are used from (**Trahmer 2008**) because of being most recent. When information is missing I used (**Scholz 1999**). Formulas or methods concerning development of the fuselage aren't given by any of them.

For the landing gear there was limited literature available: (**Roskam III and IV 1989**), (**Corke 2003**), (**Trahmer 2008**) and (**Howe 2000**). (**Roskam III and IV 1989**) is interesting for having an overview what landing gear design is all about but does not give straight answers any more because (**Roskam III and IV 1989**) uses older calculation magnitudes who are not used any more. On the other hand they do touches everything concerning the landing gear. (**Corke 2003**) gives some info and methods to calculate wheel sizes. (**Howe 2000**) on the other hand gives formulas for specific design of the landing gear like spacing and forces on the bogie. But these can not be used with preliminary design because he asks for to information that only can be become after iterations concerning the whole aircraft. Only simplified derivation by Trahmer is very useful to do preliminary design. This because the landing gear is an iteration which doesn't only include the weight of the aircraft but also wing, position center of gravity, fuselage shape, etc. This makes it very hard to predict a defining landing gear layout.

The lecture from (**Heborn 2008**) gave me a good view what the problems concerning development of the landing gear are, but only little specific information was given by the lecturer. For comparing the tool with reality, several aircraft were chosen out of (**Jane's 07-08**) which has a lot of info about every plane in production. When info was missing the website of (**Boeing**) gave extra info. The website of (**Airbus**) on the otherhand lacks on info and the only resort is (**Jane's 07-08**) when info is wanted. For checking the layout of several aircraft concerning galleys toilets and especially emergency exits (**Aviation Safety**) was more then helpful. All its info can also be found in (**Jane's 07-08**) but because of the book his size a quick look on the website explains a lot.

Special attention has to be taken with airplanes that fall under the older regulations or under other ones like the FAR. For example the use of other emergny exits see chapter 2.2.2 these exits exist under the FAR but not under the CS. This could give difficulties when comparing aircrafts in the tool.

1.4 Report structure

- Chapter 2** Contains how the part of the tool: Fuselage and cabin works, what methods have been used and what the standard given inputs are.
- Chapter 3** Deals with how the landing gear tool works and what methods are used for creating the tool.
- Chapter 4** Compares the tools output with real values taken from the aircraft A320, ATR 72 and Boeing 777-200 and stretched 777-300.
- Appendix A** Gives an extraction out of the CS.25 dealing with the emergency exits.
- Appendix B** This chapter contains ACN vlues for general aircraft
- Appendix C** Screenshots of the tool
- Appendix D** This is a CD-ROM, which contains this report in PDF-format and the created Microsoft Excel spreadsheet.

2 Fuselage and cabin

We make a proposition for the fuselage and cabin by asking a minimum of input data; most of them come from statistical data others are totally defined by the users to achieve his/her goal aircraft.

With this input we calculate -by using several methods found in literature or using simple geometry- all the dimensions of the aircraft. The most of the methods used can be bypassed by the user, for example there is a proposition for the number of seats abreast but can be adjusted by the user if preferred.

Screenshots of the tool can be seen in Appendix C

2.1 Input values

For making propositions for aircraft a minimum of input is used. The input is splitted up in two major categories, input which is commonly changed –Primary input- and input which keeps their values -secondary or limitations input-.

2.1.1 Primary input values

These are the most important inputs for the tool, these inputs could be or are commonly used for designing the fuselage.

- **Range of passengers**

This range gives the user the opportunity not to specify a specific amount of passengers but to have a market range as input. The best manor is not to give a big range; the stretched or shrunken version of the airplane will be calculated in the tool also.

- **Goal of the l/d**

This input decides which of the three purposed aircraft is chosen for more detailed calculations (see chapter 2.3).

The ideal value for the least amount of resistance in flight for l/d is 6. For production and space reasons an average value of 8 is seen as an optimal value. For stretched versions, l/d can go to 14, as for shrunken versions of the aircraft to a minimum of 5. (Scholz 1999)

According to (Trahmer 2008) a slenderness ratio close to 10 or 11 gives the “best” efficiency in terms of access, weight, drag etc. For good ground operation a long higher ratio could be handy but 10 is often a good balance.

- **Aisle height and floor lowering**

The height of the floor to the ceiling, or aisle height, and the lowering of the floor from the horizontal center line of the aircraft are deciding the diameter in case of smaller aircraft. In this case it is interesting to lower the floor more than average because there is almost no cargo, so by lowering the floor the aircraft diameter is reduced. Visualization of these parameters are shown in Figure 2.1

Typical aisle height at aisle is >2m (Trahmer 2008) and floor lowering between the value of 0...1m with an average of 0.6m. (Scholz 1999)

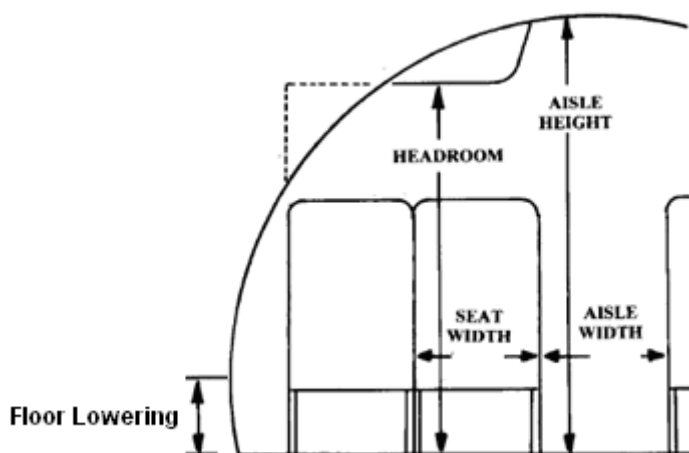


Figure 2.1 Important cabin measurements, derived from (Schmitt 1998)

- **Thickness of the fuselage and the floor**

These input values are a function of the cabin diameter but have to be adjusted after the choice of the “standard” aircraft. This is because of iteration problems and the choice not to use macros.

Formulas (2.1) and (2.2) for these input values are derived from (Trahmer 2008) graphs as seen on Figure 2.2-3

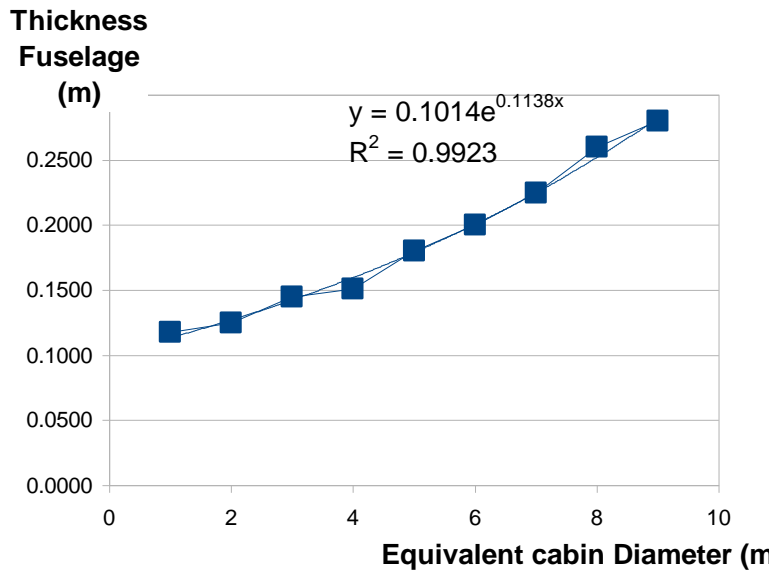


Figure 2.2 Thickness of the fuselage as a function of the equivalent cabin diameter derived from (Trahmer 2008)

$$\text{Thickness fuselage} = 0.1014 * e^{0.1138 * \text{equivalent diameter}} \quad (2.1)$$

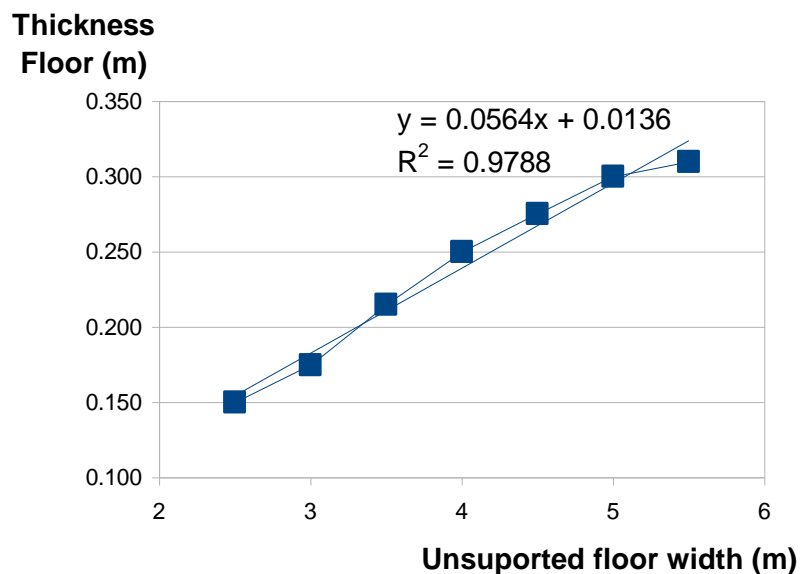


Figure 2.3 Thickness of the floor as a function of the unsupported floor width derived from (Trahmer 2008)

$$\text{Floor thickness} = 0.0564 * \text{unported floor width} + 0.036 \quad (2.2)$$

For more info see also Figure 2.4.

- **Seat, aisle**

These inputs are important for creating the kind of class desired by the user of the tool. The adjustment of these could decide if the cabin layout is considered “high density” or “economy class” or to go further and be only “business” or “first class”. The standard values inputted are considered to be economy class, this because of the consideration that the plane is primarily designed to have as much economy class passengers as possible and later on some of these seats are left behind and changed by higher class ones.

Table 2.1 Past, today and future seat and aisle measurements (**Trahmer 2008**)

1" = 25.4mm

		Sitzkissen	Armlehnen	Doppelbank	Gang
Economy	damals	17.2	2.0	40.4	18.0
	heute	18.0	2.0	42.0	19.0
	morgen	18.5	2.0	43.0	20.0
	irgendwann	?	?	?	?
Business	damals	20.0	2.0	46.0	22.0
	heute	20.0	4.0	52.0	23.0
	morgen	21.0	4.0	54.0	24.0
First	damals	20.0	4.0	52.0	20.0
	heute	21.0	5.0	57.0	20.0
	morgen	30.0	4.0	nur Einzelsitze	25.0

The initial values given are economy class and can be seen in Table 2.1

The values used are the values used for today. With designing future aircraft it could be interesting to use the future values, when doing research on older aircraft the past values can be used.

Attention has to be taken for the aisle width and the height of the armrest. **(CS.25)** implies that above a certain height in the aisle -if the aisle is slim enough- the aisle has to be wider. This could give extra diameter to the fuselage. See Table 2.2.

Table 2.2 Width of aisle extracted from **(CS.25)****JAR 25.815 Width of aisle**
[(See ACJ 25.815)]

The passenger aisle width at any point between seats must equal or exceed the values in the following table:

Passenger seating capacity	Minimum passenger aisle width (inches)	
	Less than 25 inches from floor	25 inches and more from floor
10 or less	12*	15
11 to 19	12	20
20 or more	15	20

* A narrower width not less than 9 inches may be approved when substantiated by tests found necessary by the Authority.

[Amdt. 16, 01.05.03]

- **Seat pitch**

The pitch determines in a large matter the length of the aircraft. The value taken for this is economy class and is 0.7m (**Howe 2000**).

- **Stretched and shrunken amount of passengers**

For designing the stretched and shrunken version of the tool an amount of passengers is asked. This is then converted into a certain length.

2.1.2 Secondary input values

These inputs are not commonly changed because they are considered fixed values which can not be used as parameters in preliminary designing a fuselage.

- **Measurements of a person**

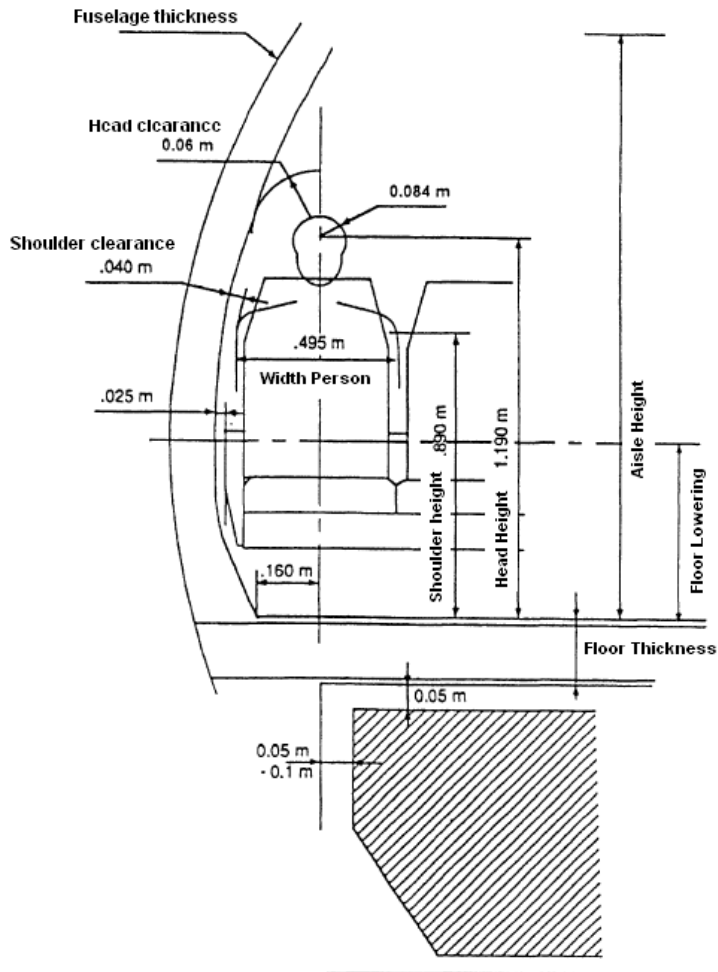


Figure 2.4 Passenger measurements and clearances derived from (Schmitt 1998)

On Figure 2.4 can be seen: all the important parameters of the person side of view: the shoulder and head clearance, seat height, person width, head and shoulder height and also the distance from the side to the person's centerline (0.160m).

- **Toilet and galleys length**

Only the length of toilets and galleys are input values, the amount will be calculated but can be adjusted during the design process.

Typical length (meaning in the longitudinal direction of the plane) of a galley is 0.65m and for a toilet 1m (Howe 2000). The width of the toilet and galley are not considered in the tool because commonly the distance from the aisle to the next aisle or wall can only contain one toilet or galley.

- **Tail and nose/cockpit length**

See chapter 2.5 for more explanation why cockpit length is used (**Trahmer 2008**).

See Figure 2.5-6.

Between these limit values length to diameter ratios are used.

Given by (**Schmitt 1998**):

- Tail length to diameter: 3.5
- Nose length to diameter: 1.7

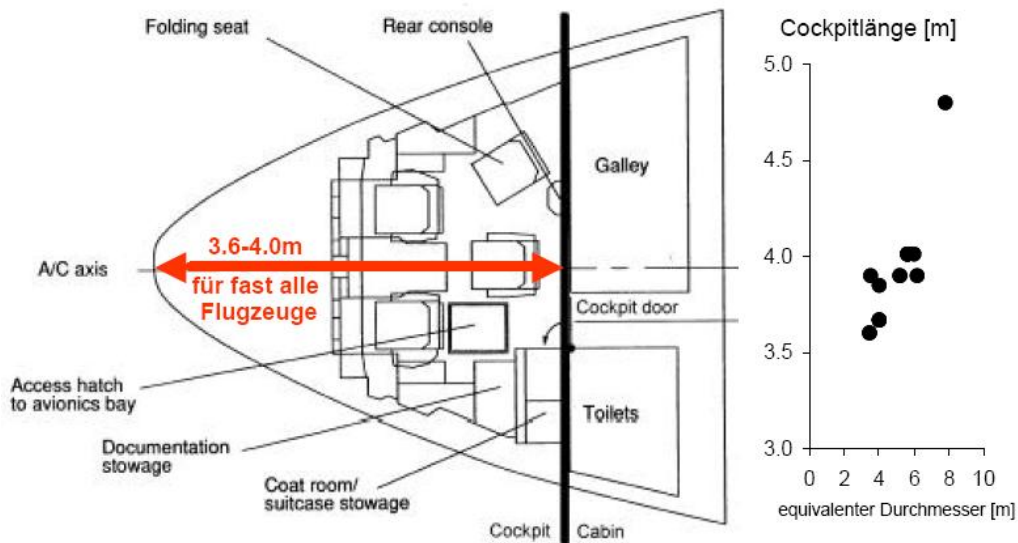


Figure 2.5 Cockpit length (**Trahmer 2008**).

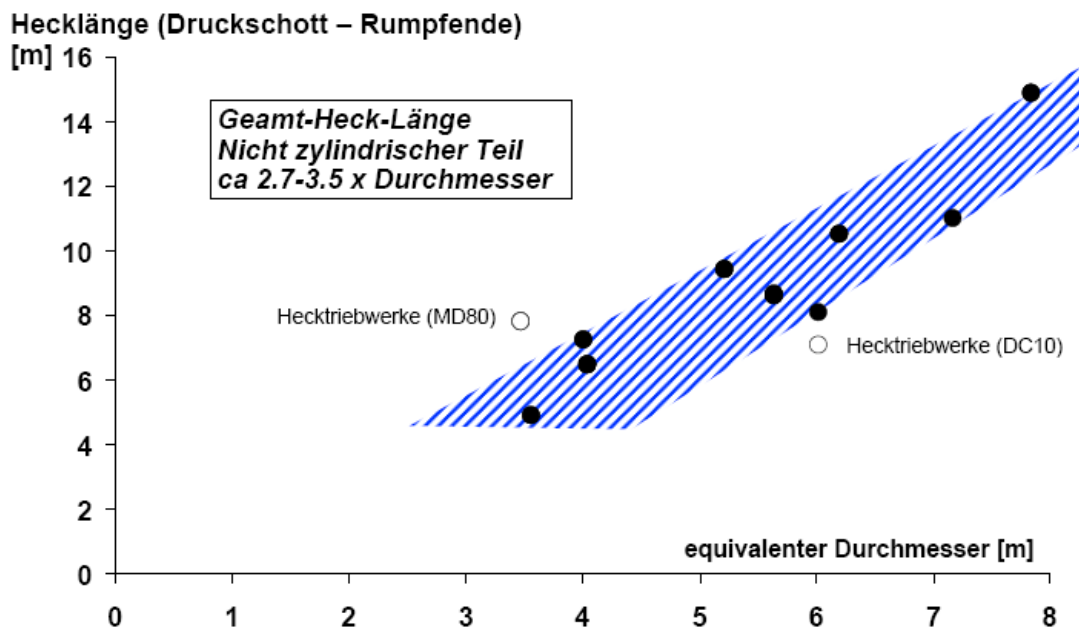


Figure 2.6 Aft tail length as a function of the equivalent diameter (**Trahmer 2008**).

2.2 Calculation methods/ Formulas

In this chapter, all the methods used for getting all the output data and formulas are explained. This gives the knowledge how the tools base is made. To explain the methods, the explanation is split up in the floor plan and the cross section; in the base code of the tool both of these parts are intensively connected.

2.2.1 Cross section

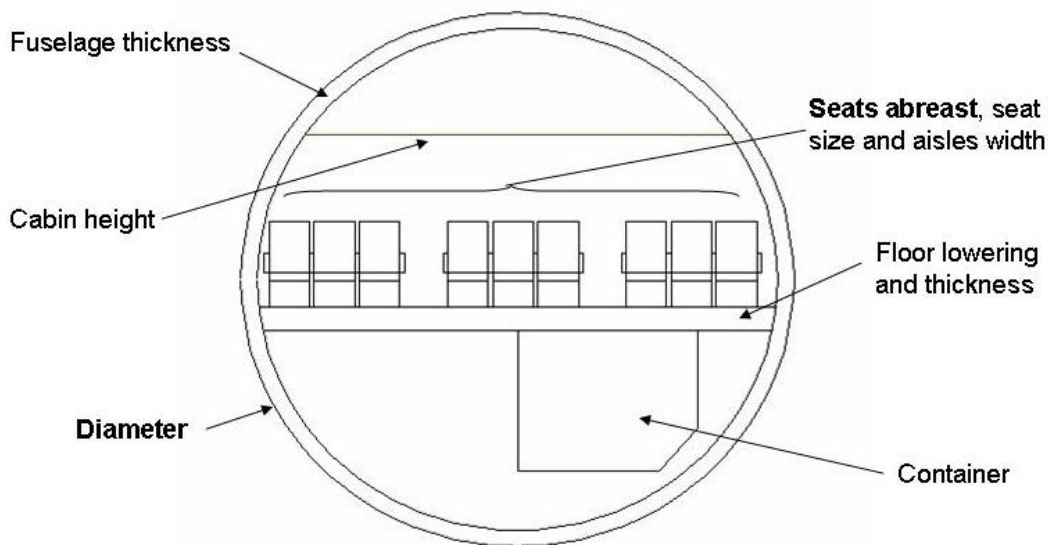


Figure 2.7 Cross section and properties

The seats abreast and the diameter of the fuselage are the most important properties of the airplane's cross section; placing a container in the belly of the airplane could be important, especially with bigger airplanes.

The number of seats abreast (N_{SA}) is determined by use of a statistical formula (2.3) given by (Scholz 1999):

$$N_{SA} = 0.45\sqrt{N_{Pax}} \quad (2.3)$$

And is only determined by N_{pax} . There can only be 3 seats next to each other that reach to an main aisle. This limits the seats abreast for one aisle till 6 and for twin aisle till 12.

The arrangement of the seats is proposed by the tool and is shown in Table 2.3:

Table 2.3 Cross section seats and aisle layout

seats abreast	layout
1	○ _
2	○ ○ _
3	○ ○ ○ _
4	○ ○ _ ○ ○
5	○ ○ ○ _ ○ ○
6	○ ○ ○ _ ○ ○ ○
7	○ ○ _ ○ ○ ○ _ ○ ○
8	○ ○ _ ○ ○ ○ ○ _ ○ ○
9	○ ○ ○ _ ○ ○ ○ _ ○ ○ ○
10	○ ○ ○ _ ○ ○ ○ ○ _ ○ ○ ○
11	○ ○ ○ _ ○ ○ ○ ○ ○ _ ○ ○ ○
12	○ ○ ○ _ ○ ○ ○ ○ ○ ○ _ ○ ○ ○

With “O” = seat and “_” = aisle

The diameter on the other hand is not only calculated by the amount of seats abreast but also by the following:

- The fitting of a container
- The floor lowering and thickness
- The fuselage thickness
- Cabin height
- Seat size and aisle width
- Measurement of the person and his clearance

The numbers of seats abreast are calculated, the width of these seats and aisle does not define the fuselage cross section measurements because the later is not square. The parameters above have to be taken in concern with determining the diameter of the cabin. With these parameters and simple trigonometry, we can calculate different diameters that could determine the cabin diameter:

- **because of interference fuselage with armrest or seat height:**

Because the fuselage is not square it could happen that the seat interferes with the round fuselage, as can be seen in Figure 2.8.

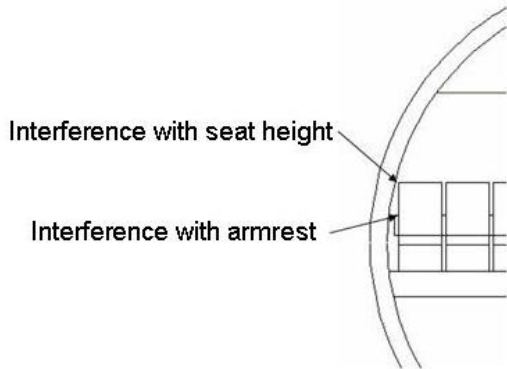


Figure 2.8 Interference with armrest and seat height

- **determined by the cabin height:**

With smaller fuselages the diameter becomes so small that the seats abreast do not determine the diameter, but instead the cabin height does. See Figure 2.9.

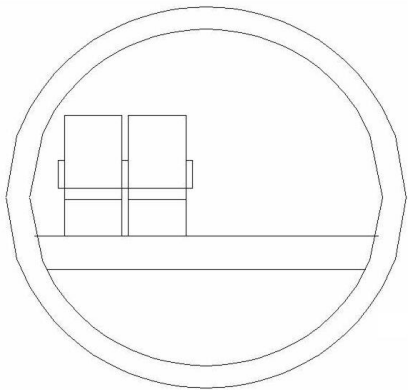


Figure 2.9 Fuselage diameter determined by cabin height

- **determined by head and shoulder clearance:**

The person sitting the closest to the fuselage must have head and shoulder clearance for psychological and safety reasons. See Figure 2.10.

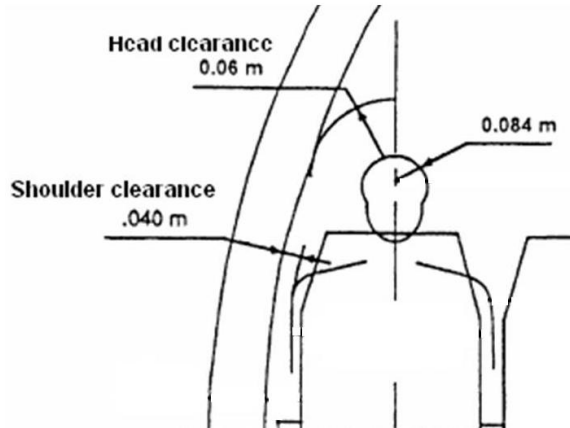


Figure 2.10 Shoulder and head clearance derived from (Schmitt 1998)

- **because of the fitting of a container:**

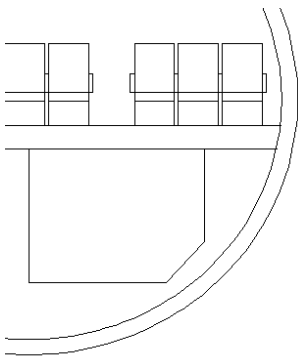
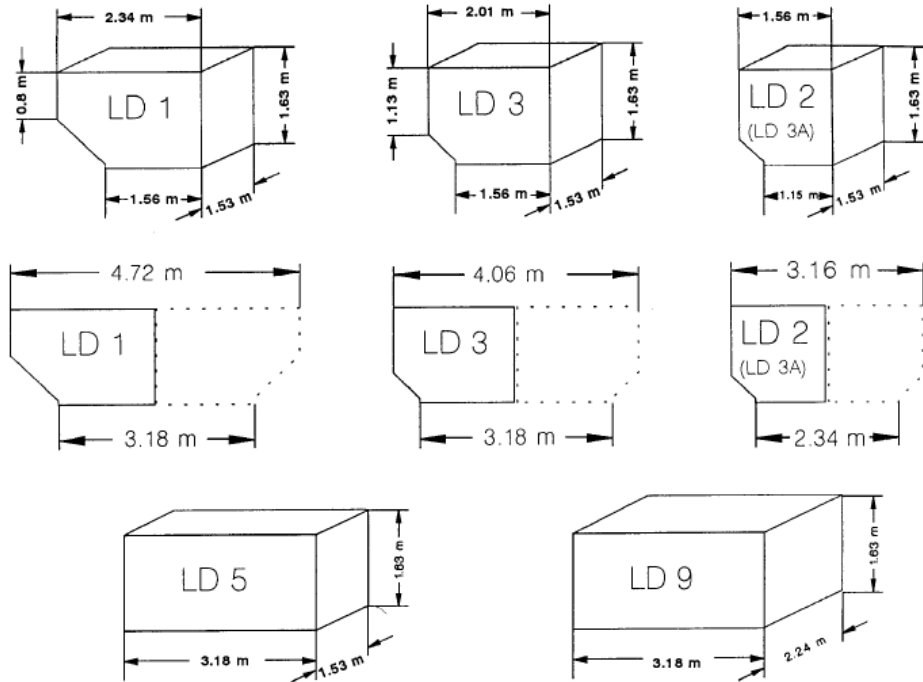


Figure 2.11 Diameter determined by the container

The increase of the diameter because of the container integration has to be done manually by the visual part of the tool as seen on Figure 2.11

Some Kinds of containers can be seen in Table 2.3

Table 2.3 Some types of containers (Marckwardt 1998)



	Nutzvolumen in [m] ³	Eigenmasse in [kg]
LD 1	4.9	75
LD 3	4.5	70
LD 2	3.4	60
LD 5	6.9	180
LD 9	9.9	200

Übliche Paletten	
m x m	inch x inch
2.24 x 1.38	88 x 54
2.24 x 2.75	88 x 108
2.24 x 3.18	88 x 125
2.44 x 3.18	96 x 125

The thickness of the floor and fuselage, and also the floor lowering, are integrated when calculating the diameters.

When we calculate all these diameters, the maximum of these diameter gives us the one needed for the fuselage of the aircraft.

2.2.2 The floor plan/ fuselage layout

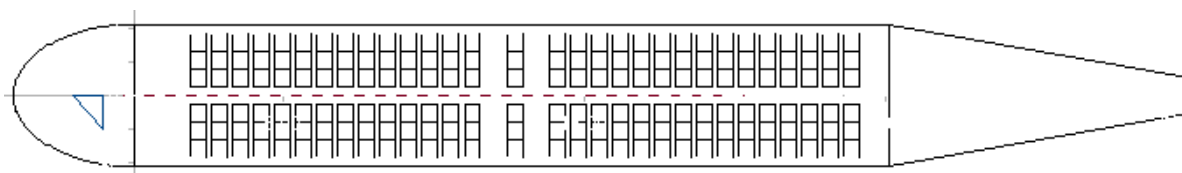


Figure 2.12 Example of a fuselage layout

The fuselage consists out of the cockpit and the tail length, an amount emergency exits, seats, galleys and toilets that are carefully laid out in the floor plan as seen in Figure 2.12. The positioning of exits, galleys and toilets is best to be done manually. For the amount and length of these outputs different tables and data are given by (CS.25) or were statistical found.

- **Emergency exits and cross aisles**

The minimum amount of emergency exits are explicitly given by (CS.25), see Appendix A.

The tool is designed to give as less emergency exits as possible, this because of high density designing point of view. Type II and III must be put over wing.

In the JAR regulations Type B and C lying between the Type A and I with 75 and 65 additional passengers are allowed. These are left behind in the tool because the tool is designed to follow the CS regulations. Also crew emergency exits are not integrated; this is only a yes or no question depending on if there is a separate cabin for the pilot, yes or no.

For the cross aisles (which are the aisles in the lateral direction of the plane that go from the main aisle to the emergency exits) the CS prescripts in CS 25.813 a fixed width numbers given in Figure 2.13.

(a) There must be a passageway leading from each main aisle to each Type I, Type II, or Type A emergency exit and between individual passenger areas. If two or more main aisles are provided, there must be a cross aisle leading directly to each passageway between the exit and the nearest main aisle. Each passageway leading to a Type A exit must be unobstructed and at least 91 cm (36 inches) wide. Other passageways and cross aisles must be unobstructed and at least 51 cm (20 inches) wide. Unless there are two or more main aisles, each Type A exit must be located so that there is passenger flow along the main aisle to that exit from both the forward and aft directions.

Figure 2.13 Extraction out of CS 25.813

In the tool there has been taken an average width for each cross aisle.

The method that has been used to integrate the emergency exits is based on a simple proposition of exits for each amount of passengers. This makes it easy to change if necessary. Type IV is left behind out of the tool because of no use with passenger aircraft.

- **Seats**

With use of the seats abreast and amount of passengers it is easy to calculate the amount of passengers of a row lengthwise.

$$N_{pax_{Row}} = \frac{N_{pax}}{N_{seats\ abreast}} \quad (2.4)$$

This times the pitch plus introducing the cross aisles, toilets and galleys, makes the length of a passenger row. Formula (2.4)

- **Amount of toilets and galleys**

This amount is statistically given by (Howe 2000):

Typically there is at least one galley needed for each 120 passengers.

At least one toilet for each 50 passengers is required, with a greater number on longer flights.

In high density configured fuselages there are often less toilets/galleys provided.

- **Length of cabin**

In the first estimation of the standard plane the formula (2.5) is used given by (Howe 2000):

$$\left[\left(\frac{N_{pax}}{N_{sa}} + N_{galleys} \right) * p + N_{toilets} + 0.8 * N_{cross\ aisles} \right] \quad (2.5)$$

The formula is expressed in meters. When the toilets, galleys and emergency exits are laid out manually special care has to be made with the placing otherwise this could result in a wrong exact cabin length.

- **Cockpit length/Aft Tail length**

Knowing the nose/cockpit (see also chapter 2.5) length to diameter we can easily make a proposition for the cockpit length. For the tail length we use the tail length to diameter ratio.

With larger and smaller aircraft this length is much too big or too small to fit a cockpit in. That's why the tool asks for minimum and maximum values. Idem with the tail length.

The shapes of nose and tail on the graph of the tool are only for visual control and may not be considered realistic.

2.3 How the tool works/ should be used

All the methods and formulas shown before do not give any idea how the tool should be used, therefore this chapter which explains in what order the aircraft has to be used.

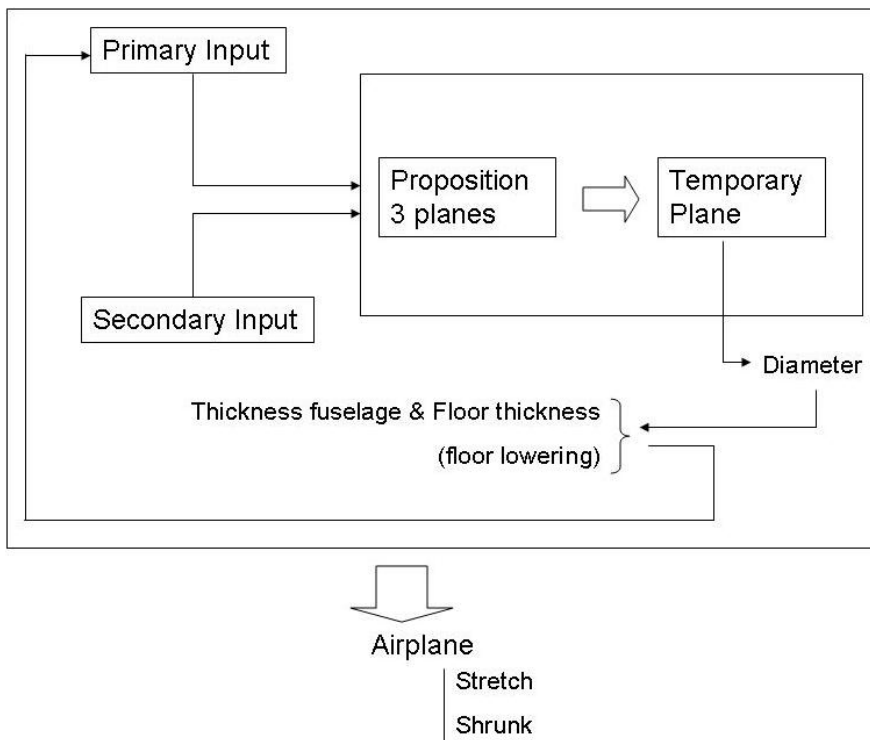


Figure 2.14 Block diagram for tool usage

A simplification of how the tool works can be seen in Figure 2.14. To choose the most sufficient aircraft the tool asks for a range of passengers that gives the tolerance of the core market wherefore the aircraft is designed for. With these two boundary values (minimum and maximum) and other primary and secondary inputs three airplanes are proposed, based on the two boundary passenger values and the average between the two.

With these 3 proposed airplanes we calculate all primary specifications. The most important one of these is seats abreast. This specification determines the diameter and length of the airplane.

Together with a goal l/d , the tool chooses what airplane suits best to our goal l/d . Of course each one of these airplanes can be chosen as the airplane which continues further in the tool for deeper and more precise calculations.

The thickness of the floor and fuselage have to be iterated manually. Because the diameter is calculated with these values and these values are calculated with the diameter.

Therefore we have to select a few times the new proposition for these values.

With this iteration we get a certain diameter which introduces an exact l/d (this has to be checked and compared to the goal l/d . When designing smaller aircraft without big cargo holding the floor could be lowered to reduce the diameter.

All this gives us an airplane with its shrunk and stretched versions.

- **Arranging emergency exits, toilets and galleys**

The arranging is very complicated to make automatic. According to (Trahmer 2008) there is no specific method to arrange toilets and galleys.

Sometimes toilets are placed in the beginning and the end of the fuselage and galleys in the front, aft and maybe in the middle of the airplane. But this differs when there is more than one class, and with the size of the aircraft.

For emergency exits on the other hand there are certain guidelines that have to be considered. For example Type II and type III should be placed over a wing, symmetrical placing of exits, emergency exits can not be placed further than 60 feet from each other, etc. (for more information see (CS.25) and Appendix A). The placing of certain exits is not as easy as it seems, for example: they have to be accessible for all kinds of ground operation exits and the emergency slides may not conflict with engines and wing.

The tool automatically places all the galleys, toilets and emergency exits in the beginning of the cabin. If the user wants, he can place these manually. When done manually the airplane length can be influenced unwontedly. This has to be taken in consideration.

On the floor plan the exits are not shown, only the cross aisle for these exits, these are shown the same way like the toilets and galleys as white areas. See Figure 2.12.

- **Integration of an container**

This has to be done by checking visually if a container is able to fit in the cargo compartment. If not the diameter and seats abreast can be adjusted manually. The question if the container fits has to be considered visually by the user by looking at the graphical output.

2.4 Output

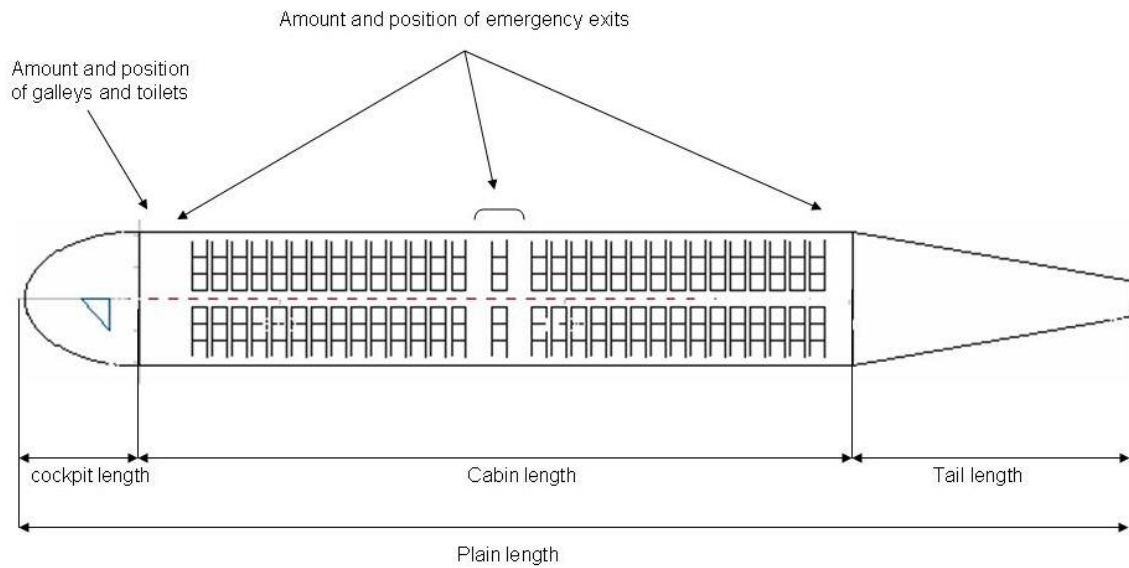


Figure 2.15.a Visualization output data

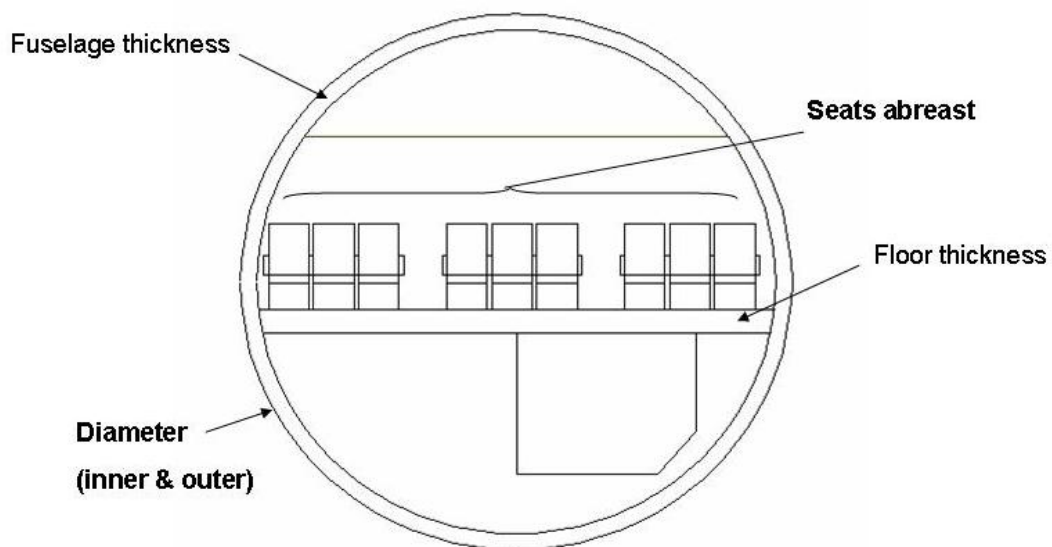


Figure 2.15.b Visualization output data

As output we have for all the aircraft (standard, stretched and shrunk):

- Diameter (inner and outer)
- Floor and fuselage thickness
- Seats abreast
- Cockpit length
- Tail length

For each of the aircraft we have an:

- l/d
- Cabin length exact and calculated by **(Howe 2000)**
- Plane length exact and calculated by **(Howe 2000)**
- Type and amount of emergency exits
- Amount of passengers
- Amount of toilets and galleys

Most of these outputs are shown on Figures 2.15.a-b

The cabin length is estimated by using **(Howe 2000)** and calculated exact with use of the visual part of the tool. For more info see conclusion in chapter 4

2.5 Range of use

The design goal of this tool is for single deck passenger aircraft. For smaller executive airplanes the tool could be used but is not that handy to use.

For very large passenger aircraft it is not ideal to use a single deck using this tool. Double decks are weight wise much more efficient but due to the single deck limitation of my tool it is not calculable. The tool works until 735 passengers.

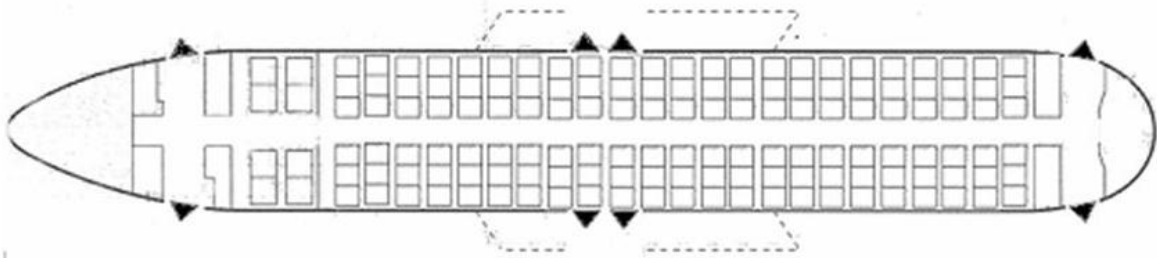
When using such a large amount of passengers in single deck there is a lot of lost space because of the large diameter, also the length of the airplane will be so long that there will be a significant increase of weight because of the bigger bending moment.

2.6 To be taken in consideration

When reading the output of the Tool some things have to be taken in consideration when the output has to be evaluated.

- **Cockpit length and tail length**

Reality



Tool

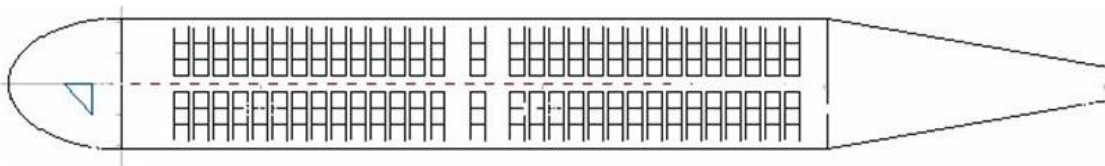


Figure 2.16 Comparison reality and tool fuselage

As can be seen in Figure 2.16 there are some major differences between the reality and the tool. First of all it has to be said that the aft tail section and nose is not drawn realistic. In reality the cabin still exists in the nose and tail section; introducing this in the tool would be difficult because of varying diameter.

That's why some definitions have to be reconsidered when using the tool.

The nose stops where the cabin begins and cockpit ends; the tail starts where the cabin ends. The advantage is that the total airplane length is correct but the effective length of tail and nose is not. Introducing this was a trade-off, the airplane length estimations are correct but the nose and tail length will be wrong, also the seat layout of the cabin will not be perfectly shaped.

For keeping the length of tail and nose in proportions there are some limits and length and diameter ratios introduced in the tool (see Chapter2.1.2)

- **l/d**

The l/d calculated with the purposed aircraft uses a formula for length estimation by (**Howe 2000**). This estimated length could differ significantly from the more precise value later on in the tool after the selection of the standard airplane.

This means that the l/d has to be compared to the goal l/d after creating the aircraft. To make sure that the l/d is not differing too much.

- **Placing of toilets and galleys**

When done manually it could be that the galleys and toilets are wrongly placed which could make the cabin length longer then necessary.

When done automatic it could be that a toilet or galley makes the rows not balanced to compensate this it could be left behind. If the users wants to integrate it anyway the only possibility is to move seats -this is not possible in the tool- this has to be done by leaving a toilet behind and changing the length of the element.

2.7 Conclusion fuselage and cabin

When using the tool, we have to considerate that it is limited to single deck aircraft. This could make the aircraft heavier because with very long fuselages there are high bending moments also a very big diameter is necessary – this to fit a high amount of seats abreast - which results in a lot of useless space. We could say that going higher then 10 seats abreast is not interesting to do.

It could be interesting not to use the proposing aircraft part and make the aircraft more manual; this to work more targeted, when having big difference of l/d to goal stretch and shrunk function could be used to correct this. When the user is not satisfied with the amount of seats abreast this could be changed manually.

The actual layout in the tail and in the nose differs a lot from realistic aircraft but compares, this because galleys and toilets are most of the time put there. Rarely the seats abreast are adjusted to fit them in

3 Landing gear

The tool is focused on calculating tricycle landing gear layout; this layout is commonly used on civil aircrafts.

For preliminary sizing only a small proposition is given how the landing gear could look like.

Screenshots of the tool can be seen in Appendix C.

3.1 Input

Only a small amount of input is needed for the tool:

- **ACN**

This number is supposed to be between 40 and 80 and should be lower or equal to the airport PCN

- **Kind of aircraft**

Is the aircraft a Transport bomber or a business twin jet?

- **MTOW or MTW**

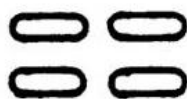
- **Kind of landing gear**

What is the layout of the landing gear unit which is needed closer calculation? Possible layouts are shown in Figure 3.1

Pair of side by side
single tyres



Four wheel
bogie



Four wheel bogie with
every wheel twin tyres

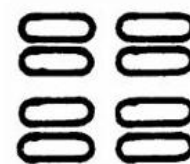


Figure 3.1 Possible layouts of landing gear units derived from (*Roskam IV 1989*)

3.2 Calculation Methods/ Formulas

Because of the simplicity of the tool, the method of how the tool works is explained in the following sequence.

The first step is to get the number of wheels

- **Derived single wheel load**

Formula (3.1) is given by (Trahmer 2008) and is:

$$\text{Derived single wheel load} = \frac{ACN_{limit}}{2} \quad (3.1)$$

With this load we can calculate the

- **Nr of wheels**

$$N_{wheels} = \frac{MTOW}{\text{Derived single wheel load}} \quad (3.2)$$

Formula (3.2) given by (Howe 2000)

Instead of MTOW it is better to use MTW (depends on what is given).

After this we determine what wheel sizes are needed for the nose and main landing gear, by use of formulas (3.3) and (3.4).

- **Wheel sizes**

Out of (Corke 2003) we know that 90% is carried by the main landing gear and 10% by the nose gear.

$$W_{main} = \frac{0.9 * MTOW}{N_{wheels}} \quad (\text{Howe 2000})$$

$$\text{Main diameter or width(in.)} = AW_{main}^B \quad (\text{Corke 2003}) \quad (3.4)$$

With A and B seen in Table 3.1.

Table 3.1 A and B constants (**Corke 2003**)

	diameter		width	
	A	B	A	B
business twin jet	2.69	0.251	1.17	0.216
Transport bomber	1.63	0.315	0.104	0.48

The nose wheel size are in general 60% of the size of the main landing gear (**Roskam IV 1989**)

Next we determine the bogie and spacing of the axle. The landing gear unit has to be chosen manual so the spacing can be calculated.

- **Actual load capacity for a unit:**

This can be derived with formula (3.5)

$$F = (1 + k(\frac{D}{100})) \quad (\text{Howe 2000}) \quad (3.5)$$

With K derived from Table 3.2

Table 3.2 Values for k (**Howe 2000**)

Kind of unit	K
pair of side by side single tires	1.1
four-wheel bogie	4
four wheel bogie each wheel with twin tires	4.8

- **The spacing is**

determined by the layout of the unit and diameter. See Table 3.3.

Table 3.3 Spacing determined by unit layout (**Howe 2000**)

pair of side by side single tires	0.8*D
pair of twin tires	1.1*D
Bogie	1.2*D

3.3 How the tool works/should be used

The using of the tool is very easy because of limited input. After giving the input values a direct output is delivered.

3.4 Output

As output we get the basic information:

- The number of wheels
- The size of nose and main landing gear wheels
- Spacing between the wheels of the specific unit
- The actual load capacity of the unit

3.5 Range of use

The tool is designed for a tricycle landing gear layout for only a few landing gear units. When only the given landing gear units are used there is no principle limit for the range by means of amount of wheels or MTOW.

3.6 To be taken in consideration

Normally there is interference between the wheels on a bogie which changes the actual ACN. For preliminarily design this could be left behind ,for closer inspection this is not negligible. Sometimes other bogies are used for space or ACN reasons, finding data for these bogies is hard which limits the tool to some specific landing gear units.

3.7 Conclusion

Because of very limited information and calculating methods found in literature, the size of the tool became quite small. The landing gear layout is a long iterating design problem with much possibility's, there is no certain method to follow as it differs for every aircraft (citation out of **(Hebborn 2008)**).

Using the tool for a further design then preliminary is not ideal because of the not correct ACN and the limited amount of landing gear units.

4 Examples

In this chapter, specifications of several aircraft are inputted in the tool and compared to the real values. This to know more about the reliability of the tool.

For the example airplanes several aircraft which cover the range of the tool are taken. These aircraft are the Atr 72, the Airbus A320 and Boeing 777-200. The principle of getting certain input is explained in the first example. In the other examples the same principle is used. All input and reality values comes from (**Jane's 07-08**), ACN tables that can be found in Appendix B or are standard values given by the tool.

4.1 Atr 72

The inputted values can be seen in Table 4.1

Table 4.1 inputted fuselage values for Atr 72

N_{pax}	74	
p	74	cm
Aisle width	0.46	m

The output of the fuselage can be seen in table 4.2 and seen in figure 4.1.a-b.

Table 4.2 Output fuselage Atr 72

	ouput	reality
purposed seats abreast	4 (3)	4
emergency exits	2x Type A	2 type I and 2x type III
$l_{\text{Cabin Howe}}$	16.2	19.2
$l_{\text{Aircraft Howe}}$	30.2	27.2
$l_{\text{Cabin Exact}}$	16.2	19.2
$l_{\text{Aircraft Exact}}$	30.2	27.2
D_{outer}	3.0	2.9
D_{inner}	2.7	2.6

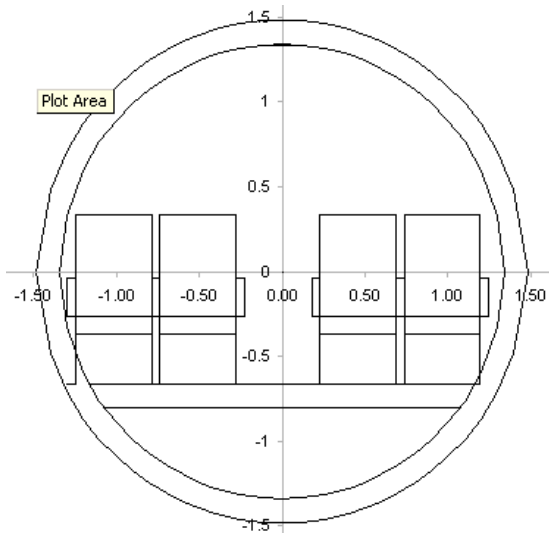


Figure 4.1.a Output fuselage Atr 72



Figure 4.1.b Output fuselage Atr 72

The tool proposes an amount of seats abreast of 3, to decently be able to compare the output of the tool with the reality this is manually adjusted to 4 seats abreast. When we compare the data we can see results are almost the same as the real values of the aircraft. The kind of emergency exits differs, because the tool is designed to have as less as possible.

For the input for the landing gear, I looked in ACN tables out of Appendix B for the biggest MTOW and the lowest ACN, this to be able to design targeted to the most strict requirements. We find a MTOW of 21 tons and a ACN of 11. This give the following output as can be seen in table 4.3

Table 4.3 Output landing gear Atr 72

	tool	reality	
Nr wheels	4	4	
wheel diameter	30.3	/	inch
wheel width	9.0	/	inch
tyre diameter	/	34	inch
tyre width	/	10	inch

The wheel diameter is not given for any of the aircraft and tyre diameters can not be calculated because of the lack of a formula. But we can compare to the tyre sizes which are given in (Jane's 07-08) to the wheel sizes. The values seem to be realistic.

4.2 A320

Table 4.4 Inputted fuselage values A320

N_{pax}	179
aisle width	0.48 m

Table 4.5 Output fuselage values A320

	ouput	reality
purposed seats abreast	6	6
emergency exits	4x Type A	4x type I & 4x Type III
$l_{\text{Cabin Howe}}$	28.1	27.5
$l_{\text{Aircraft Howe}}$	42.1	37.6
$l_{\text{Cabin Exact}}$	26.7	27.5
$l_{\text{Aircraft Exact}}$	40.7	37.6
D_{outer}	4.0	4.0
D_{inner}	3.7	3.7

We can see that length of the cabin is not as expected. This is because of not knowing the pitch of the seats and how many toilets and galleys the aircraft has in high density configuration. The kind of emergency exits differ also. This because that the tool is designed to have as less as possible.

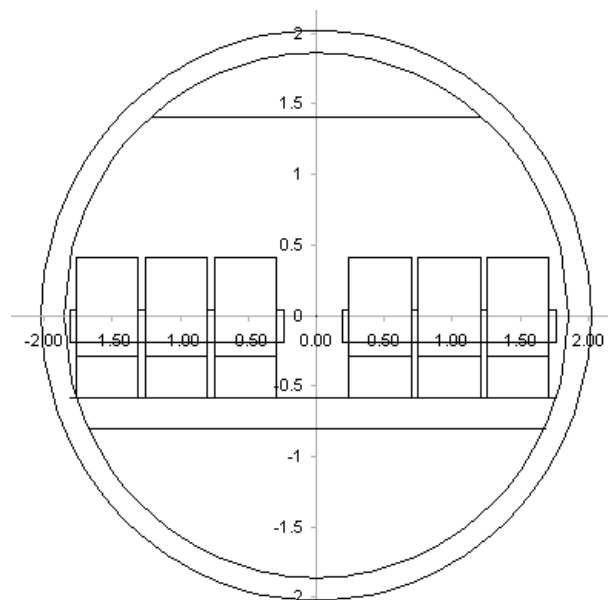


Figure 4.2a Output fuselage A320

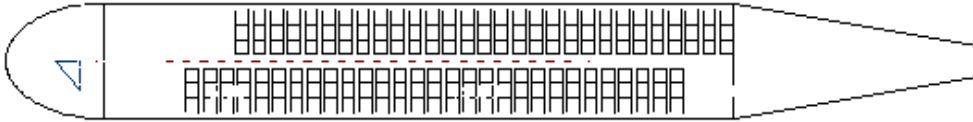


Figure 4.2b Output fuselage A320

Input for the landing gear is a MTOW of 66.7 tons and a ACN of 35

Table 4.6 Output landing gear A320

	tool	reality	
Nr wheels	4	4	
tyre diameter	43.7	✓	inch
tyre width	15.6	✓	inch
wheel diameter	✓	46	inch
wheel width	✓	16	inch

4.3 777-200

Table 4.7 Input fuselage 777-200

N_{pax}	440	
Pitch	79	cm

Table 4.8 Output fuselage 777-200

	output	200
purposed seats abreast	10 (9)	10
emergency exits	8x Type A	8x Type A
l_{Cabin} Howe	48.3	49.1
$l_{Aircraft}$ Howe	62.3	62.94
l_{Cabin} Exact	41.5	49.1
$l_{Aircraft}$ Exact	55.5	62.94
D_{outer}	6.7	6.2
D_{inner}	6.3	5.87

The proposal of the amount of seats abreast was 9, this has been manually adjusted to 10.

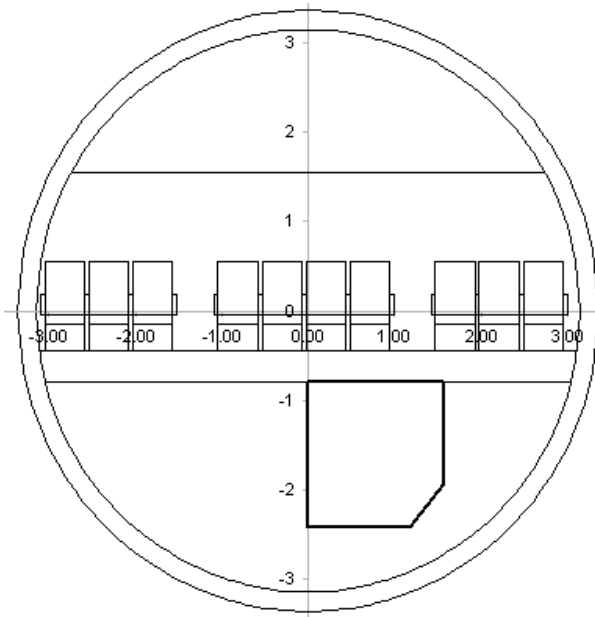


Figure 4.3.a Output fuselage 777-200



Figure 4.3 b Output fuselage 777-200

For the input of the landing gear an ACN of 54 was taken and a MTOW of 294.5 ton.

Table 4.9 Output landing gear A320

	tool	reality	
Nr wheels	13	12	
tyre diameter	45.3	/	inch
tyre width	16.5	/	inch
wheel diameter	/	49	
wheel width	/	19.0	

4.4 Conclusions examples

We can conclude that the tool works good and gives reliable output. The lengths calculated by using **(Howe 2000)** and the exact calculated lenghts are comparable, sometimes one is more correct then the other. The exaxt calculating is very usefull when galleys and toilets are being arranged, while the estimation by **(Howe 2000)** gives a fast but reliable estimation. It would be interesting if an statistical research was done to know which one is more precise.

Acknowledgements

I would like to thank my parents for supporting me and giving me the opportunity to do my studies abroad.

Then I would also like to thank my supervisors Prof. Dr.-Ing. Dieter Scholz and Dipl.-Ing. Kolja Seeckt, I know that it was only because of your support that it was possible to do my studies here in Hamburg. You gave me a motivating working environment and helpful co-workers who helped me with more than my work, they have now become some of my dearest friends.

And last but not least, Michael for helping me to make this thesis as English as possible.

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Appendix A: Info Emergency exits

Extraction out of CS.25 derived from (Scholz 1989)

CS.25.807 Emergency exits																																									
<p>(a) Type. For the purpose of this CS-25, the types of exits are defined as follows:</p> <p>(1) Type I. This type is a floor level exit with a rectangular opening of not less than 24 inches (609.6mm) wide by 48 inches (1.219 m) high, with corner radii not greater than one-third the width of the exit.</p> <p>(2) Type II. This type is a rectangular opening of not less than 20 inches (508 mm) wide by 44 inches (1.12 m) high, with corner radii not greater than one-third the width of the exit. Type II exits must be floor level exits unless located over the wing, in which case they may not have a step-up inside the aeroplane of more than 10 inches (254 mm) nor a step-down outside the aeroplane of more than 17 inches (431.8 mm).</p> <p>(3) Type III. This type is a rectangular opening of not less than 20 inches (508 mm) wide by 36 inches (914.4 mm) high, with corner radii not greater than one-third the width of the exit, and with a step-up inside the aeroplane of not more than 20 inches (508 mm). If the exit is located over the wing, the step-down outside the aeroplane may not exceed 27 inches (685.8 mm).</p> <p>(4) Type IV. This type is a rectangular opening of not less than 19 inches (482.6 mm) wide by 26 inches (660.4 mm) high, with corner radii not greater than one-third the width of the exit, located over the wing, with a step-up inside the aeroplane of not more than 29 inches (736.6 mm) and a step-down outside the aeroplane of not more than 36 inches (914.4 mm).</p> <p>(5) Ventral. This type is an exit from the passenger compartment through the pressure shell and the bottom fuselage skin. The dimensions and physical configuration of this type of exit must allow at least the same rate of egress as a Type I exit with the aeroplane in the normal ground attitude, with landing gear extended.</p> <p>(6) Tail cone. This type is an aft exit from the passenger compartment through the pressure shell and through an openable cone of the fuselage aft of the pressure shell. The means of opening the tail cone must be simple and obvious and must employ a single operation.</p> <p>(7) Type A. This type is a floor level exit with a rectangular opening of not less than 42 inches (1.067 m) wide by 72 inches (1.829 m) high with corner radii not greater than one-sixth of the width of the exit.</p> <p>(b) Step down distance. Step down distance, as used in this paragraph, means the actual distance between the bottom of the required opening and a usable foot hold, extending out from the fuselage, that is large enough to be effective without searching by sight or feel.</p> <p>(c) Over-sized exits. Openings larger than those specified in this paragraph, whether or not of rectangular shape, may be used if the specified rectangular opening can be inscribed within the opening and the base of the inscribed rectangular opening meets the specified step-up and step-down heights.</p> <p>(d) Passenger emergency exits. Except as provided in sub-paragraphs (d)(3) to (7) of this paragraph, the minimum number and type of passenger emergency exits is as follows:</p> <p>(1) For passenger seating configurations of 1 to 299 seats - Passenger seating Emergency exits for each side of the fuselage configuration (crewmember seats not included)</p>																																									
Passenger seat configuration (crew member seats not included)	Emergency exits for each side of the fuselage																																								
	<table border="1"> <thead> <tr> <th></th> <th>Type I</th> <th>Type II</th> <th>Type III</th> <th>Type IV</th> </tr> </thead> <tbody> <tr> <td>1 to 9</td> <td></td> <td></td> <td></td> <td>1</td> </tr> <tr> <td>10 to 19</td> <td></td> <td></td> <td>1</td> <td></td> </tr> <tr> <td>20 to 39</td> <td></td> <td>1</td> <td>1</td> <td></td> </tr> <tr> <td>40 to 79</td> <td>1</td> <td></td> <td>1</td> <td></td> </tr> <tr> <td>80 to 109</td> <td>1</td> <td></td> <td>2</td> <td></td> </tr> <tr> <td>110 to 139</td> <td>2</td> <td></td> <td>1</td> <td></td> </tr> <tr> <td>140 to 179</td> <td>2</td> <td></td> <td>2</td> <td></td> </tr> </tbody> </table>		Type I	Type II	Type III	Type IV	1 to 9				1	10 to 19			1		20 to 39		1	1		40 to 79	1		1		80 to 109	1		2		110 to 139	2		1		140 to 179	2		2	
	Type I	Type II	Type III	Type IV																																					
1 to 9				1																																					
10 to 19			1																																						
20 to 39		1	1																																						
40 to 79	1		1																																						
80 to 109	1		2																																						
110 to 139	2		1																																						
140 to 179	2		2																																						
Additional exits are required for passenger seating configurations greater than 179 seats in accordance with the following table:																																									
Additional emergency exits (each side of fuselage)	Increase in passenger seating configuration allowed																																								
Type A	110																																								
Type I	45																																								
Type II	40																																								
Type III	35																																								
<p>(2) For passenger seating configurations greater than 299 seats, each emergency exit in the side of the fuselage must be either a Type A or a Type I. A passenger seating configuration of 110 seats is allowed for each pair of Type A exits and a passenger seating configuration of 45 seats is allowed for each pair of Type I exits.</p> <p>(3) If a passenger ventral or tail cone exit is installed and that exit provides at least the same rate of egress as a Type III exit with the aeroplane in the most adverse exit opening condition that would result from the collapse of one or more legs of the landing gear, an increase in the passenger seating configuration beyond the limits specified in sub-paragraph (d)(1) or (2) of this paragraph may be allowed as follows:</p> <p>(i) For a ventral exit, 12 additional passenger seats.</p>																																									

- (ii) For a tail cone exit incorporating a floor level opening of not less than 20 inches (508 mm) wide by 60 inches (1-524 m) high, with corner radii not greater than one-third the width of the exit, in the pressure shell and incorporating an approved assist means in accordance with CS 25.809(h), 25 additional passenger seats.
- (iii) For a tail cone exit incorporating an opening in the pressure shell which is at least equivalent to a Type III emergency exit with respect to dimensions, step-up and step-down distance, and with the top of the opening not less than 56 inches (1-422 m) from the passenger compartment floor, 15 additional passenger seats.
- (4) For aeroplanes on which the vertical location of the wing does not allow the installation of over-wing exits, an exit of at least the dimensions of a Type III exit must be installed instead of each Type IV exit required by sub-paragraph (1) of this paragraph.
- (5) ...
- (6) ...
- (7) For an aeroplane that is required to have more than one passenger emergency exit for each side of the fuselage, no passenger emergency exit shall be more than 60 feet (18-288 m) from any adjacent passenger emergency exit on the same side of the same deck of the fuselage, as measured parallel to the aeroplane's longitudinal axis between the nearest exit edges.
- (e) **Ditching emergency exits for passengers.** Ditching emergency exits must be provided in accordance with the following requirements whether or not certification with ditching provisions is requested:
 - (1) For aeroplanes that have a passenger seating configuration of nine seats or less, excluding pilots seats, one exit above the waterline in each side of the aeroplane, meeting at least the dimensions of a Type IV exit.
 - (2) For aeroplanes that have a passenger seating configuration of 10 seats or more, excluding pilots seats, one exit above the waterline in a side of the aeroplane, meeting at least the dimensions of a Type III exit for each unit (or part of a unit) of 35 passenger seats, but no less than two such exits in the passenger cabin, [with one on each side of the aeroplane. The passenger seat/exit ratio may be increased through the use of larger exits, or other means, provided it is shown that the evacuation capability during ditching has been improved accordingly.
 - (3) If it is impractical to locate side exits above the waterline, the side exits must be replaced by an equal number of readily accessible overhead hatches of not less than the dimensions of a Type III exit, except that for aeroplanes with a passenger configuration of 35 seats or less, excluding pilots seats, the two required Type III side exits need be replaced by only one overhead hatch.
- (f) **Flight crew emergency exits.** For aeroplanes in which the proximity of passenger emergency exits to the flight crew area does not offer a convenient and readily accessible means of evacuation of the flight crew, and for all aeroplanes having a passenger seating capacity greater than 20, flight crew exits shall be located in the flight crew area. Such exits shall be of sufficient size and so located as to permit rapid evacuation by the crew. One exit shall be provided on each side of the aeroplane; or, alternatively, a top hatch shall be provided. Each exit must encompass an unobstructed rectangular opening of at least 19 by 20 inches (482-6 by 508 mm) unless satisfactory exit utility can be demonstrated by a typical crew member.

Appendix B: ACN's

Tabel B.1 Aircraft classification numbers derived from (Transport Canada 2001)

AIRCRAFT CLASSIFICATION NUMBERS (ACN's)

<i>Aircraft</i>	<i>Weight Max/Min (kN)</i>	<i>Tire Pressure (MPa)</i>	<i>Flexible Pavement Subgrades</i>				<i>Rigid Pavement Subgrades</i>			
			<i>CBR</i>				<i>k (MPa/m)</i>			
			<i>High</i>	<i>Medium</i>	<i>Low</i>	<i>Vr Low</i>	<i>High</i>	<i>Medium</i>	<i>Low</i>	<i>Ult Low</i>
			<i>A</i>	<i>B</i>	<i>C</i>	<i>D</i>	<i>A</i>	<i>B</i>	<i>C</i>	<i>D</i>
			15	10	6	3	150	80	40	20
A319-100	744 382	1.38	39 18	40 18	45 20	50 23	44 20	46 21	49 22	51 24
A320-100	667 390	1.21	35 19	36 19	40 21	46 24	38 30	41 22	43 23	45 25
A320-200	725 402	1.03	37 19	39 19	44 21	50 25	40 20	43 21	45 23	48 24
A320-200	744 422	1.14	39 20	40 21	45 22	51 26	42 22	45 23	48 25	50 26
A320-200	759 441	1.44	41 22	42 22	47 24	53 28	46 24	49 26	51 27	53 29
A320-200 (Optional Bogie)	725 402	1.22	20 10	22 10	26 11	35 15	19 9	23 10	27 12	31 14
A320-212 (Optional 4-Wheel Bogie)	764 490	1.22	21 12	23 13	28 15	38 20	21 11	24 13	29 16	33 18
ATR 42 (Aerospatiale)	182 110	0.72	9 5	10 5	11 6	13 7	10 6	11 6	12 7	12 7
ATR 72 (Aerospatiale)	211 125	0.79	11 6	12 6	14 7	15 8	13 7	14 7	14 8	15 8
B777-200	2433 1400	1.38	51 25	58 27	71 31	99 43	40 23	50 23	65 28	81 35
B777-200 ER	2822 1425	1.38	63 25	71 27	90 32	121 44	53 23	69 25	89 31	108 39
B777-200 X	3278 1600	1.38	78 29	90 32	114 38	148 53	61 27	80 27	104 34	126 43
B777-300	2945 1600	1.48	68 30	76 32	97 38	129 53	54 27	69 28	89 35	109 43

Manual adjusting of the standard aircraft

Diameter automatic chosen: **Plain 1**
 m

seats abreast

Aircraft	<u>1</u>	<u>2</u>	<u>3</u>
N_{aisles} proposal	2	2	2
N_{sa} proposal	9	10	11
extra:	0	0	0

Figure C.1.b Screenshot fuselage tool

3 Output values

	<u>standard</u>	<u>stretched</u>	<u>shrunk</u>	
N_{pax}	400	500	320	
l_{Cabin} Howe	44.4	55.7	34.7	m
l_{Aircraft} Howe	58.4	55.7	34.7	m
l/d Howe	9.5	9.0	5.6	
I	0	0	0	
II	0	0	0	
III	0	0	0	
type A	8	10	6	
galleys	3	4	2	
toilets	8	10	6	

	<u>graphic</u>	
l_{Cabin} Exact	39.0	m
l_{Aircraft} Exact	53.0	m
l_{Tail}	10.0	m
l_{Nose}	4.0	m
l/d_{exact}	8.6	
D_{outer}	6.2	m
D_{inner}	5.8	m

Cross section

Figure C.1.c Screenshot fuselage tool

Landing gear design

Kind of aircraft:	<input type="text" value="Transport bomber"/>	N_{wheels, main landing gear}	<input type="text" value="8"/>																		
A C N goal	<input type="text" value="30"/>	Derived Single wheel load	<input type="text" value="15 t"/>																		
MTOW(t) or MRM	<input type="text" value="120"/>	Tire dimensions	<table border="1" style="border-collapse: collapse; width: 100%;"> <thead> <tr> <th colspan="2"></th> <th style="text-align: center;">inch</th> <th style="text-align: center;">m</th> </tr> </thead> <tbody> <tr> <td rowspan="2" style="text-align: right;">main gear</td> <td style="text-align: left;">tire diameter</td> <td style="text-align: center;">42.2</td> <td style="text-align: center;">1.07</td> </tr> <tr> <td style="text-align: left;">tire width</td> <td style="text-align: center;">14.8</td> <td style="text-align: center;">0.38</td> </tr> <tr> <td rowspan="2" style="text-align: right;">nose gear</td> <td style="text-align: left;">tire diameter</td> <td style="text-align: center;">25.3</td> <td style="text-align: center;">0.64</td> </tr> <tr> <td style="text-align: left;">tire width</td> <td style="text-align: center;">8.9</td> <td style="text-align: center;">0.23</td> </tr> </tbody> </table>			inch	m	main gear	tire diameter	42.2	1.07	tire width	14.8	0.38	nose gear	tire diameter	25.3	0.64	tire width	8.9	0.23
		inch	m																		
main gear	tire diameter	42.2	1.07																		
	tire width	14.8	0.38																		
nose gear	tire diameter	25.3	0.64																		
	tire width	8.9	0.23																		
Kind of gear:	<input type="text" value="Four-wheel bogie"/>	actual load capacity	<input type="text" value="117.4 t"/>																		
		spacing wheels	<input type="text" value="1.18 m"/>																		

Figure C.2 Screenshot Landing gear tool

Appendix D: CD-ROM

This is a CD-ROM, which contains this report in PDF-format and the created *Microsoft Excel* spreadsheet.