UNIVERSITEIT TWENTE

TRANSPORTING GOODS IN AFRICA USING UNMANNED CARGO AIRCRAFT

Business case for the use of unmanned cargo aircraft in delivering medicines in Congo's rainforest

Supervisors:

Dr. J.M.G. Heerkens
B. Roorda
R. Zijlstra

Bacheloropdracht Technische Bedrijfskunde

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D.S. GROOTENS
S1127594

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Introduction

In recent years, unmanned transport has taken huge steps. Cars and trucks now have the ability to drive themselves, and this trend is coming to airplanes too. In this thesis, which has been carried out on behalf of Mr. Zijlstra, the main question is if and how a company can operate in transporting goods using an Unmanned Cargo Aircraft (UCA). The objective of this company, which in the rest of this report will be called 'Pedro' is to transport food and medicines in remote areas.

The objective to transport medicines means that the volume of the freight is very small. Because of these small volumes, the aircraft used doesn't have to carry more than two regular sized pallets.
An added benefit of transporting small loads is that the size and thus the weight of the aircraft can remain low, making for relatively low development and production costs. The most important side effect is that the aircraft will have high utilization rates, lowering the total transportation costs

Plan of action

The main objective of this research is to design a business model for the transportation of goods using Unmanned Cargo Aircraft over large distances.
In order to answer this problem, a number of sub problems have been set up.

1. *In what areas can an UCA be successfully deployed?*

Using earlier research on the possibilities of UCAs for cargo transportation, the most ideal location for Pedro's activities is determined. For this, a global search for the most important factors is carried out. Next, a further investigation will yield the most favorable country to set up this first business in cargo transport using unmanned aircraft.

2. *What are the costs and benefits for competitive transport?*

The current modes of transportation and their cost structures will have to be determined. These will serve as Pedro's competitors, so it is useful to know their characteristics and their strong and weak spots.

3. *What does a Business Model for Unmanned Cargo Aircraft look like?*

The current situation and the requirements imposed by the client will have to be taken together into a business model. This is done in the canvas-model, which will be explained and then Pedro's activities will be discussed to find all the important actors and structures.

4. *What are specifications for a UCA in the mentioned scenario?*

At the moment, there is no UCA for sale which is able to transport goods over large distances. This means that the requirements from the customer and the characteristics following from the business model need to be taken together into a specification list of the aircraft.

5. *What are the expected costs and benefits of a UCA?*

While there is no aircraft available, research has been done in the cost structures of large unmanned aircraft. The results of these researches will be used to determine the transport times, reliability and costs of design, usage, infrastructure and maintenance.

These costs can then be compared to the costs of the competitors, which will show the strengths and weaknesses of UCAs.

6. How can a UCA be competitive on the long run?

The strengths of UCAs will have to be maxed out in order to be competitive. This chapter will thus describe ways in which Pedro should be profitable when operating in this segment.

1 In what areas can a UCA be successfully deployed?

Pedro's business case will have to be compared to other means of transportation, and will therefore have to focus on a specific country or region. It is possible to expand the network to multiple countries, but for the sake of simplicity in laws and regulation this research will look for a region within one country, as to make the chances of UCA transportation as big as possible without it being counteracted by different countries.

1.1 Determining areas

Before different modes of transport can be compared to each other, it is important to determine the area in which Pedro will conduct its business. Earlier research has shown that a UCA is faster than a truck, and that its speed advantage grows with bad infrastructure (Prent, 2013). Another precondition is that the region isn't served by much regular air transport able to take cargo with it as belly freight, because belly freight is the cheapest way of transporting cargo, and UCAs won't be able to compete. Another point is regulation and acceptation by the regular public. Flying over heavily populated areas isn't expected to happen in the coming years, so the area must be sparsely populated.
The combination of bad infrastructure, low levels of internal air transport and low occupied areas is found in Alaska, the Scandinavian Countries, South America and Africa.
Alaska has a decent economy with an organized supply of goods, leaving little perspective for a successful business case for starting up unmanned cargo transportation.
Scandinavia got a large tundra on the north with remote access to the southern part, but lacks the population to provide initial demand and growth of market share. While the inhabitants have purchasing power, the number of possible clients is too small for large scale operations.
Based on the preconditions stated above, the only region in South America with opportunities for unmanned cargo transportation is the amazon rainforest, and within Africa there are lots of rainforests and deserts.
A further analysis on Africa and the amazon is needed to see which country offers the best opportunities for a Business Model using Unmanned Cargo Aircraft.

1.2 Choosing a country

Within Africa there are lots of countries with vast, nearly impassable types of terrain. A quick scan on the map shows a number of countries which qualify for Pedro's activities, based on the preconditions stated above. These countries and the Brazilian rainforest are shown below in Table 1 and are scaled on a number of criterions, which are shown below. The scores are based on publicly available data (Wikipedia, 2015). The criterions are based on the geographical assets of the countries like range and market size, because they drive the potential for Pedro's activities. One other criterion is added to address the political stability, as stable countries will have better opportunities for a successful business case.

Political stability

Peace is a precondition for starting a business. Countries with a mix of bad infrastructure and low internal transportation are most of the time developing or unstable countries. Because of this, a research has to be done on the stability of a country. The power of government, regional factions and corruption have to be taken into account.
A safe region will score ++, and an unsafe region will get a score of --. The Democratic Republic Congo scores a 0, because of the wars in the past years and the attempts of the government to increase the

safety. While the country as a whole isn't safe yet, the rainforest in the northwest aren't affected much by the tribes in the east, and the changes for a safe and successful business case are increasing.

Area

For a UCA to be able to fly efficiently, the area which will be surfaced needs to be large. A UCA can be efficient from ranges of 300 kilometers (Prent, 2013), and the maximum flying distance of a single plane is set to 3000 km. It is possible to fly longer legs, but for the sake of this research, which will look for a case with 1 hub from where the planes will be flying, a maximum of 3000 km is chosen.
++ can be scored if the area is at least 500*500 kilometers wide, with the scores declining if the area gets smaller.

Population in area

The population in the surfaced area needs to be large enough to start a regular service. In the first place the market for food and medicines needs to be big enough to start a delivery service, but if the company grows, more freight can be transported in and out of the region. This is measured by looking at the population and density of the region.
A high score can be obtained if the area features cities and villages of acceptable sizes to serve as destination cities. The absence of large or permanent villages result in a low score.

Demographic distribution

The need for medicines is greatly affected by the demographic distribution of the targeted area. Children, adults and elderly need different quantities and types of food, medicines and other goods, so a balanced distribution of the population will enlarge the amount of cargo to be transported.
Most African countries have a distribution with around 40% of the population being 15 years or younger, resulting in one large group of targets. The purchasing power and influence of this group is however small, so they aren't an interesting group to start business with.

Expected growth of market

The chances of a successful transportation system are better when the market can be expanded with extra operations, like contracts with shippers to ensure Pedro of high utilization rates. Within a developed country, many of these opportunities are already taken, so Pedro can only grow if it takes contract previously held by other companies. A developing country, especially when rich of resources, has much better forecasts of providing growth and contracts. The African countries with a relative young population show great prospects when basic needs can be delivered, increasing quality of life and after that the need for more goods.

Development of infrastructure

Within the chosen countries there are huge differences in the availability and quality of the infrastructure. The fewer usable roads, the better UCA's can be used to transport time-critical goods like medicines, so the higher the score on this criterion will be.

Availability of airstrips

There need to be enough possibilities to land and refuel the planes. While it is possible to land on grass fields, the availability of airstrips with fuel can reduce the need to return to the home base, increasing the productivity of the service.

Criterion	Brazil	Congo	Algeria	Sudan	Sudan	Nigeria	Gabon	Cameroon
Type of area	Rainforest	Rainforest	Desert	Desert	Rainforest	Rainforest	Rainforest	Rainforest
Political stability		0	++	+	-		++	-
Area	++	++	++	+	-	+	--	-
Population (m)		81,6	39,5	40,2		182,2	1,4	22,5
density		33	15,9	16,4		188,9	5,5	39,7
Population in area	-	+	--	--	+	+	+	+
Demographic distribution	23/70 ++	46/51 -	28/66 ++	40/55 -	-	42/55 -	40/56 -	44/53 -
Expected growth of market	-	++	-	++	++	++	++	++
Development of infrastructure	+	++	--	++	+	+	--	+
availability of airstrips	-	++	++	++	++	+	++	+

Table 1, criteria for choosing a country

The rainforest of Brazil and Congo, and the desert of Algeria have the most ideal area to be able to compete with trucks. Gabon has a too dense road network and has too few inhabitants to be competitive.

Despite the immense dimensions of deserts, the lack of villages and therefore market opportunities for cargo transport make them unattractive areas.

This leaves the rainforests of Brazil and Congo as the most ideal countries. Comparing the population densities of both regions shows that the population in Brazil is widely dispersed, leading to small villages with low cargo demand per village (Wikipedia, 28-10-2015). The DRC on the other hand features large cities across the rainforest, resulting in a high prospected demand and thus the best opportunities for creating a transportation network using UCAs (Development Daily).

The Democratic Republic of Congo seems to be the most ideal country, despite its low score on political stability. In the past there have been wars, but the government is trying its best to develop Congo into a secure country. It is expected that the stability will improve over the coming years, so that Pedro can start its business by flying in much needed medicines.

1.3 Geographical features Congo

Now that the rainforest of the Democratic Republic of Congo is chosen as target area, it is important to find out in which ways the current transportation is set up. The rainforest is positioned in the northwest, and has an area of about 500 x 600 kilometers. The targeted area can be enlarged with pieces of the rainforest located in different countries (Wikipedia, 2015), but for the sake of legalization and simplicity this is not taken into account in this research.

Figure 1, Map of Congo

Congo has two large international airports, at Kinshasa and Lubumbashi. Lubumbashi airport is mainly used for regional flights, while Kinshasa has direct connections to other continents, making N'djili Airport in Kinshasa the most suitable one. The Luxemburg airline CargoLux flies a regular service from Europe to Kinshasa (Cargolux, 2012), and in this research we consider most goods to be shipped to arrive via CargoLux planes, and so Pedro will operate from Kinshasa.

Most of the cities in the DRC have airstrips, so most of the villages in the rainforest will be accessible by UCA. In order to make a proper comparison between all possible modes of transportation, the destinations in this research will be the main cities in the rainforest. These cities are Mbandaka, Gemena, Gbadolite, Bumba and Kisangani. They are shown in Figure 1 with Gemena laying between Mbandaka and Gbadolite. These cities are all located along the Congo River and have limited road links, and a decent population of at least 100.000, ranging up to close to a million (Development Daily), (Wikipedia 2015).

1.4 Transported goods

The Democratic Republic of Congo is one of the poorest countries in the world, with an economy destroyed by years of war and cities cut off from transportation routes. The United Nations Food Program is carrying out a program to support the war-affected population of East Congo, but also flies to the rainforest to deliver food to these cities. There is still a large and underfed population in the rainforest, and as a result of that a big market for food-delivery (World Food Programme, 2015).

2 What are the costs and benefits for competitive transport?

2.1 Modes of transport

Congo's rainforest is traversed by the Congo River. As a result of this, there are no direct connections between Kinshasa and the destination cities. The current ways to reach them are with trucks, barges and airplane. They will be discussed below.

2.1.1 Truck

Congo has 2250 km of paved highways, with most of it running from Kinshasa to the southeast. The roads in the rainforest are in bad shape, and are practically impassable during the wet season when the roads turn into mud tracks. This means that driving through the rainforest is virtually impossible, forcing trucks to drive around it for the majority of the time. The start of the route therefore is over the paved highways, while the remainder of the route traverses over gravel and sandy roads directing north. The mean speed will be influenced mostly by the amount of time spend on badly maintained roads. Study shows that an average speed of 170 kilometers per day can be assumed (Al Jazeera, 2012). This can degrade with heavy rainfall, or make transportation with trucks impossible.
Mbandaka is not reachable via roads. The distances and times needed are shown below in Table 2. Google Maps is used to determine the distances.

Destination	Region	km	time
Kisangani	Orientale	2627	15d 11h
Mbandaka	Equateur	-	
Bumba	Equateur	3269	19d 6h
Gemena	Equateur	3707	21d 20h
Gbadolite	Equateur	3652	21d 12h

Table 2, trucking distances and times

2.1.2 Barge

The most used way of transport in the rainforest is with a barge, which is pushed by a tugboat. Using this mode of transport, Mbandaka, Bumba and Kisangani can be reached. To get to Gemena and Gbadolite, the freight can be transported via barge to Lisala, where a truck will take the goods for the last part of the trip (Virunga Amani, 2015).
The barges are in essence pure cargo ships, but are used as public transport and traveling marketplaces too. This means the barges stop at every town they pass to trade, reducing the speed of the barges to a maximum of 75 kilometers per day. The total transportation times are shown in Table 3.

		Barge			**Truck**		**Total**	
From	to	km	time	frequency	km	time	km	time
Kinshasa	Kisangani	1750	24d	1-2w			1750	24d
Kinshasa	Mbandaka	650	9d	Daily			650	9d
Kinshasa	Bumba	1300	18d				1300	18d
Kinshasa	Lisala	1180	16d					
Lisala	Gemena				292	1d 18h	1472	17d 18h
Lisala	Gbadolite				333	2d	1513	18 d

Table 3, barge distances and times

2.1.3 Airplane

While there are airstrips in the destination cities, there are no scheduled flights. It is therefore not possible to calculate costs of regular air transport. The flight distances are available, so a calculation can be made by choosing a charter plane (Worldatlas). The flight distances are shown in Table 4.

destination	region	Airport	Plane	
Kinshasa		FZAA	Km	Time
Kisangani	Orientale	FZIC	1190,01	1h 45m
Mbandaka	Equateur	FZEA	557,87	1h
Bumba	Equateur	FZFU	1042,17	4h 15m
Gemena	Equateur	FZFK	925,79	2h 30m
Gbadolite	Equateur	FZFD	1094,8	-

Table 4, airplane distances and flight times

2.2 Operating costs

The operating costs of all means of transport can be divided in fixed and variable costs.
The fixed costs are all costs which have to be paid whether freight is being transported or not. This consists of driver's salaries, depreciation, licenses. Variable costs are costs that are discounted over the distance traveled. The main attributes are fuel and maintenance.
The transportation quantity for the UCA is set to 2 tons freight per flight. In order to compare the different modes of transportation in the best possible way, all transportation costs are scaled back to the tonnage of the UCA.

2.2.1 Truck

There is no data available for transport using trucks in Congo. There is however a report about the Africa Infrastructure Country Diagnostics (Teravaninthorn & Raballand, 2009) about transport prices and costs in Africa. In this report, for the four major African regions the proportions of transportation costs are calculated. Since Congo lies in Central Africa, those costs are used as transportation costs for Congo.
The road network in Congo lies mostly in the south and east, and is highly obsolete. The routes toward and in the rainforest are mostly gravel or sand. The average fleet in central Africa is obsolete, with truck ages of 15 years. Due to the age of the trucks, there are many technical issues and thus high maintenance costs. In order to earn a decent living, most truckers overload their vehicles. An average truck in the rainforest is allowed to transport 10 tons, but with 20% overloading will carry 12 tons (Nathan, 2013). For a freight of 2 tons, it is assumed that the costs will be divided linearly, transporting 2/12 tons will result in 1/6 of the total transportation costs of 1 truck.

The division of fixed and variable costs is assumed to be 30/70%. The distribution used is an average of the costs in central Africa in the AICD-report. The average costs in this report are $41,25 $/day and $1,7125 $/km, and those costs are taken as input for this study.
The percentages and costs for the different routes are shown below in Table 5, while the calculations and assumptions are discussed in appendix A.

	percentage		Kisangani	Bumba	Gemena	Gbadolite
Fixed costs						
staff	10,275		65,50	81,50	92,42	91,05
depreciation	9,6		61,19	76,15	86,35	85,07
finance	3,075		19,60	24,39	27,66	27,25
other	7,05		44,94	55,92	63,41	62,47
Variable costs						
fuel	36,925		1661,16	2067,12	2344,09	2309,31
tires	10,325		464,49	578,01	655,46	645,73
maintenance	9,8		440,88	548,62	622,13	612,90
bribes	12,95		582,59	724,96	822,10	809,90
Total costs			3340,35	4156,68	4713,61	4643,68
Transport costs			$ 556,72	$ 692,78	$ 785,60	$ 773,95

Table 5, truck transportation costs

2.2.2 Barge

There isn't any information to be found about the division of costs of transporting goods via river tugs. It is however known that there are multiple tugs operating the Congo River, pushing large barges across the river. These Tugs include Integrated Tug Barges operated by the government, in order to increase accessibility to the rainforest (Forbes).
One source indicates that the total transportation costs per ton-kilometer are three times as cheap for waterway transportation as for road freight (Megevand, 2013). This leads to transportation costs of $0,05 per ton-kilometer.
The transportation costs for the last part of the trips to Gemena and Gbadolite are calculated in the same way as the trucking costs in chapter 2.2.1., and the results are shown in Table 6.

	Kisangani	Mbandaka	Bumba	Lisala	Gemena	Gbadolite
distance	1750	650	1300	1180	292	333
ton-km	3500	1300	2600	2360		
Barge costs	$175	$65	$130	$118	$118	$118
Trucking costs					$61,88	$70,57
total	$175	$65	$130		$179,88	$188,57

Table 6, barge transportation costs

2.2.3 Airplane

A much used aircraft in Africa is the Hawker Beechcraft 1900D. This airplane can, besides people, also transport cargo and has a maximum load capacity of 2100 kg. The small payload means that all the costs are accounted to the transported cargo in this research, so the transportation costs will be high. Advantages of this transportation mode are the extremely short transport time, safety and predictability of arrival.

The used model for calculating the airplane prices can also be used when calculating for UCAs (Hoeben, 2014), and is shown below in Table 7. The calculations and underlying data are shown in appendix B. Aircraft depreciation is calculated for an airframe lifetime of 25 years, so 4% depreciation per year, or 4/365 = 0,011% per day.

Warehousing costs aren't charged at Kinshasa when transporting food and medicines. Warehousing costs will come into effect when other goods are transported, but in this business case they are set to $0.

	Kisangani	Mbandaka	Bumba	Gemena	Gbadolite
airport user charges	31,06	31,06	31,06	31,06	31,06
aircrew costs	901,65	505,69	809,04	736,15	842,02
fuel costs	779,80	437,35	699,71	636,67	728,23
aircraft depreciation	197,43	110,72	177,15	161,19	184,37
maintenance costs					
Costs of labor, airframe	1440,55	807,92	1292,59	1176,13	1345,27
Costs of labor, engine	1872,71	1050,30	1680,36	1528,96	1748,85
Costs of materials, airframe	409,65	229,75	367,58	334,46	382,56
Costs of materials, engine	532,55	298,68	477,85	434,80	497,33
warehousing costs	0	0	0	0	0
inventory costs	40,15	29,81	37,73	35,83	38,59
cargo handling costs	120	120	120	120	120
Total	$ 6.325,55	$ 3.621,27	$ 5.693,06	$ 5.195,24	$ 5.918,26

Table 7, airplane transportation costs

The costs and cost structures of these modes of transportation will be compared to the costs of UCA transportation in chapter 5.3.

3 What does a Business Model for Unmanned Cargo Aircraft look like?

3.1 What is a Business model

A business model is a structured picture of the logic of a firm and the way it operates to earn money. This is done by making clear the decisions which are being made and the consequences they have (Casadesus-Masanell & Ricart, 2009).
A way to show a business model is by using the Canvas-method (Osterwalder & Pigneur, (2009), where the focus lays on the goal of the firm, the used methods and their impact on the operations and profits.

Customer segments

The first block of Canvas looks at the customers that the new to form business has to serve. A firm can only be profitable if it is clear what the main customer is, and how to serve the different customers.

Value propositions

The value proposition is the main purpose of the firm, and the reason the customers come to the firm and make use of its services.

Channels

Channels are the ways the firm has contact with its clients in relationship with the product. This consists of communication, distribution and sales, and all other ways the customer and the firm have contact, from knowing each other's existence, via sales to after-sales.

Customer relationships

This block consists of all communication related to getting and keeping customers.

Revenue streams

The revenue stream is the profit of the firm from all different customer segments.

Key resources

Key resources are the things that make it possible to provide the customer with the product. This contains physical facilities, labor, capital and intellectual capacities.

Key activities

Key activities are the essential activities that have to be performed with the key resources to make the business model work. This contains the development, creation and maintaining of products and services

Key partnerships

Key partners are all parties that make it possible for resources and activities to be present and possible, so that the firm has the required value proposition. By making strategic choices it is possible to remain profitable on the long run.

Cost structure

The cost structure is for the most part deducible from the choices made in the other blocks, and contains all costs to be able to operate the business model.

3.2 Business model UCA

The aim of this research is to design a company which specializes in the transportation of low volumes of time-critical goods. The first step in realizing this will be to start with food and medicines, and after this is set up the business can be enlarged with the transportation of other goods.
In this model there are two types of customers recognizable: the supplier, who wants the medicines and goods to be transported to the rainforest, and the citizens who want their products to be shipped to the port. The goal of Pedro is to offer a fast and cheap way of transportation to both customer segments. Because of the inhospitable region and the difficulty to gain contact with the inhabitants it is recommended to focus first on existing transportation flows toward the region. By starting with time-critical goods towards the villages there will be a first network of regular freight flights. When the

awareness off the service grows, more people can take advantage of it and return flights will take local products to Kinshasa to sell on the local markets. The most profitable goods to be transported are gold and diamonds, ensuring the miners of a buyer and increasing their social situation (Wardell Armstrong LLP, 2007). By building the network this way the network can grow steadily, and the number and capacity of the planes can grow in the same manner. This will ensure the perfect solution for the demand of this specific region. Using unmanned aircraft means fewer or no people are needed for processing the cargo. In order to still achieve contact with all partners, all of the regular destinations need to house a representative of Pedro. This representative will be in charge of cargo handling and customer support.

The revenue from Pedro's operations will come from the transportation fees, and the ability to ensure predictable transportation times. Within the transportation market, low costs will ensure competitive prices and thus earning contracts. An added profit for UCA's above regular transportation modes is the decrease in delivery times, so that urgent and time critical cargo can be transported. This opens new possibilities and therefor enlarges the possible freight flows and profit.

The most important necessities for setting up an unmanned cargo network are planes and communication channels. Because most of the flights will leave from Kinshasa airport it makes sense to place the control center there too. Contact with planes and representatives can be obtained via satellites. It is at the moment unsure if the planes can be landed from the control center. It is imaginable that the changes of a successful touchdown and handling of the plane increase with manual landing from the landing site. Therefore, the representative on the landing site will have to be educated to land the plane, making it safer and easier to land the planes.
Before the planes are able to fly it is important to have contacts within the transportation sector, and to draft contracts to assure the future of Pedro. Beside this, on the main location of Pedro a maintenance shop needs to be established. The key partners will be the suppliers, because they will have to arrange for a steady stream of cargo to be shipped. The operational costs consist of the flying costs of the UCA, together with costs for communication, maintenance and labor. Additionally, the costs for development and depreciation of the equipment have to be taken into account.

In the business model described above, all factors of the Canvas-model have been taken into account, ensuring all significant factors to be in the model. A summary of this business model can be given by putting all the important factors together in one image, as is done in Figure 2.

<table>
<tr><th>Key Partners</th><th>Key Activities</th><th>Value Proposition</th><th>Customer Relationships</th><th>Customer Segments</th></tr>
<tr><td rowspan="3">- (Medicine) suppliers
- shippers
- Hospitals & field post</td><td>Control flights</td><td rowspan="3">Deliver fast and low cost ways of transporting essential goods</td><td>Representatives in cities</td><td rowspan="3">- (Medicine) suppliers
- Citizens</td></tr>
<tr><td>Key Resources</td><td>Channels</td></tr>
<tr><td>- UCAs
- Communication services</td><td>- UN
- Hospitals
- CargoLux</td></tr>
<tr><td>Cost Structure</td><td colspan="2">- operating costs UCA
- communication
- maintenance
- UCA development</td><td>Revenue Streams</td><td>- Transporting medicines
- Transporting other goods</td></tr>
</table>

Figure 2, UCA Canvas

4 What are specifications for a UCA in the mentioned scenario?

The business model stated above leads to design specifications for the airplane, a number of is of direct influence for the design and costs of the aircraft. There are also a number of specifications, which follow from the business model, which have to be taken into account when designing the airplane, but don't affect the costs at the moment.

4.1 Technology

The most important specification is that the airplane can fly unmanned. As a result of this, there is no need to take human safety and comfort into account, so there is no need for a pressure cabin. A traditional cockpit doesn't have to be installed either, reducing the weight of the airframe. Because of the absence of people, the design can be window-less, so the plane can be stronger while using fewer materials.

Besides these adjustments, no other special technology has to be inserted in the design. Proven technologies for propulsion and communication are easy to implement in the design and will result in higher uptime then when using newer, but less stable technologies.

Because a UCA will compete mostly with trucks and barges, it isn't necessary to fly at high speeds. It is recommendable to fly slower, and thus more economically with an air speed of 160 miles per hour.

It is to be expected that human control will still be required in the coming years. The client has therefore demanded that the plane can be controlled by a maximum of 1 pilot, but it is preferable that one pilot is able to fly multiple planes at the same time.

Because unmanned aircraft are well suited to fly over high risk areas, UCAs can gain an extra advantage if they are easily deployable in the case of humanitarian disasters. For this to work, it is necessary to be able to transport the whole system, which consists of planes and flight control, in standard sized shipping containers.

The last technological specification is that the plane should be easy and cheap to produce in masses.

4.2 User-friendliness

In the event of the airplane having to deliver emergency aid, it is presumed that the destination area doesn't have any usable airfields. Additionally, in the regular use of UCAs over inaccessible areas it is not always possible to use airfields. This leads to the specification that the plane has to be able to land on unpaved runways. To increase the number of possible landing locations, Mr. Zijlstra came with the requirement for the plane to be able to take off and land from runways with a length of 150 meters.

With using the airplane in inhospitable regions comes the need to make loading and unloading as easy as possible. This means that no heavy equipment should be needed to insert the pallets in the aircraft. In the most ideal situation, no equipment is used at all, so the aircraft can load and unload itself.

Because of the remote landing areas, you have to assume that there won't be fuel available. This means that the flying range of the aircraft needs to be big enough to make a round trip without refueling. A range of 2500 kilometers seems to be enough in this case to be able to fly to the furthest city and back, but to keep the options for future networks open a minimum of 3000 kilometers is decided.

4.3 Features

The following characteristics will be inserted in the model, a complete list of aircraft specifications is given in appendix C.

- Air speed of 160 miles per hour (257 km/h)
- Payload of 2000 kg
- Propeller-driven
- Pilot is controlling 5 planes during flight, direct control during landing and take-of
- Range of 3000 km
- Travel characteristics like cruising altitude comparable to piloted airplanes

5 What are the expected costs and benefits of a UCA?

The costs model for UCAs is estimated to be comparable to the plane model, so this model will also be used for the UCA. Before the costs and benefits of a UCA can be computed, the missing values should be estimated. These values will then be inserted in the model, after which the costs of unmanned aircraft can be calculated.

5.1 Estimating missing values

A lot of the values for flying with a UCA are the same for manned and unmanned flight. The differences are in the operating costs, maintenance costs and other costs.

5.1.1 Operating costs

The UCA will differ from manned aircraft in its speed and fuel consumption. The UCAs pilot is able to fly five aircrafts simultaneously, so the aircrew costs of a UCA will be a fifth of a manned airplane.
The speed of the UCA is set to 160 miles per hour, as specified in the above chapter.
Because of the lower and thus more economical speed, the improved design and use of lighter materials, the fuel consumption is estimated at a third of the fuel consumption of a Beechcraft (Boukema et.al., 2015). This means that the UCA will burn 32 gallons of Jet-A fuel per hour.

5.1.2 Maintenance costs

By removing the cockpit from the aircraft, the UCA itself will become much simpler than a normal airplane. The remaining parts in the cockpit are all software and will be easier to maintain than current aircraft, using less materials and thus being cheaper.
The new and simplified design of the UCA will result in less maintenance on the aircraft per flight hour. Because of the lower speed and thus lower output and requirements on the engine, the strain on the engines will be much smaller than with conventional airplanes. This means that a less sophisticated engine can be installed. This, in combination with the lower weight and better aerodynamics of the aircraft, will result in easier maintainable engines, resulting in lower maintenance times than with aircrafts currently in use.
It is likely that the UCA will be maintained by the same crews that maintain other aircraft. The costs of labor are therefore the same for manned and unmanned aircraft.

5.1.3 Miscellaneous costs

When designing a plane, the rule of thumb says that a plane can lift half of its weight. For manned propeller planes, the maximum takeoff weight can be estimated using $\frac{Payload+Fuel}{MTOW}\sim 0{,}418$, but when comparing manned and unmanned aircraft systems, it is estimated that a UCA can carry a ton extra with the same MTOW (Prent & Lugtig, 2012). To be on the safe side of the equation, the calculation is being made with an extra freight of 0,6 ton.
This results in the equation $\frac{Payload-0{,}6+Fuel}{MTOW}\sim 0{,}418, or\ MTOW = \frac{Payload-0{,}6+Fuel}{0{,}418}$.
With the maximum range of the UCA of 3000 km, the maximum fuel consumption will account to 388,35 gallon, or 1,176 ton of Jet A fuel.
The maximum Takeoff weight can therefore be calculated as $\frac{2-0{,}6+1{,}176}{0{,}418} = 6{,}16$ ton.

The price of UCAs is hard to predict, but because of the need to design an entirely new plane and therefore higher costs, the price is estimated as double the price of a Beechcraft, making it $10 million.

The actual costs are expected to be lower rather than higher than 10 million, but in order to not give false hope for the UCAs perspective, the calculation is done with $10 million.

Because of the absence of pilots, it is not necessary to return to the home base as often as with manned aircraft. In addition, crew rest is no longer a restricting factor, so the plane can fly long legs shortly after each other making it possible to fly multiple routes a day. Making use of the available daylight, the aircraft utilization can therefore be enlarged and is estimated at 14 hours a day.
The estimated values are shown below in Table 8, next to the corresponding values applicable for the Beechcraft.

	description	unit	Beech	UCA
A	aircrew costs per block hour	$/hour	312,5	62,5
speed	airplane speed	mile/h	310	160
FC/h	fuel consumption per hour	gallon/h	95,84	31,946667
MATairframe	airframe and systems maintenance materials cost per block hour	$/hr	141,98	70,99
MATengine	engine maintenance materials cost per block hour	$/hr	141,98	70,99
MHRairframe	number of airframe and systems maintenance man-hours per block hour	hr	1,986998	0,993499
MHRengine	number of engine maintenance hours per block hour	hr	1,986998	0,993499
MMTOW	maximum takeoff weight	ton	7,764	6,16268
Pa/c new	aircraft new price	$	4.995.000	10.000.000
Rlabor	aircraft maintenance labor rate per man-hour	$/hr	251,27	251,27
U	average utilization	hr/day	8	14

Table 8, differences between airplane and UCA

5.2 Operating costs of UCA

When the specifications of the UCA are inserted in the model, the operating costs are computed as in Table 9.

	Kisangani	Mbandaka	Bumba	Gemena	Gbadolite
airport user charges	24,65	24,65	24,65	24,65	24,65
aircrew costs	320,09	166,66	284,21	255,96	296,98
fuel costs	461,39	240,22	409,67	368,95	428,08
aircraft depreciation	400,90	208,73	355,95	320,58	371,96
maintenance costs					
C_lab, airframe	1278,51	665,66	1135,18	1022,36	1186,21
C_lab, engine	1662,07	865,35	1475,73	1329,06	1542,07
C_mat, airframe	363,58	189,29	322,81	290,73	337,33
C_mat, engine	472,65	246,08	419,66	377,95	438,52

warehousing costs	0,00	0,00	0,00	0,00	0,00
inventory costs	58,25	38,36	53,62	49,96	55,27
cargo handling costs	120,00	120,00	120,00	120,00	120,00
Total	$ 5.162,09	$ 2.765,01	$ 4.601,47	$ 4.160,20	$ 4.801,08

Table 9, UCA transportation costs

5.3 Comparing costs

When comparing the costs of all the calculated means of transportation, a few things are striking. They are represented in Table 10 and discussed below.

The values under 'ratio' are calculated by dividing the total costs and time of the common ways of transportation by the value for the UCA. When a transportation mode is faster or cheaper than the UCA, this will result in a score under 1. The last line in the table, marked as 'Insufficiency' is the multiplication of the ratios, or $\frac{costs\ x}{costs\ UCA} \cdot \frac{time\ x}{tume\ UCA}$. A high insufficiency means that the transportation costs and time don't add up in favor of the specific transportation mode, while a low score means it is the preferred mode of transportation, with the score for the UCA set to 1.

	Truck	Barge	Plane	UCA
staff	$ 13,77		$ 758,91	$ 264,78
depreciation	$ 12,87		$ 166,17	$ 331,62
Finance *	$ 4,12			
other	$ 9,45		$ 156,42	$ 171,09
fuel	$ 349,24		$ 656,35	$ 381,66
tires	$ 97,65			
maintenance	$ 92,69		$ 3.581,76	$ 3.124,16
bribes + charges	$ 122,48		$ 31,06	$ 24,65
total costs ($)	$ 702,26	$ 147,69	$ 5.350,67	$ 4.297,97
cost ratio	0,163394	0,034363	1,2449301	1
time (h)	468	337,9059	2,4285097	4,2364875
time ratio	110,4689	79,76086	0,5732366	1
overall score	18,04997	2,74081	0,7136395	1

Table 10, Transportation costs comparison

* In this comparison, only the direct operating costs are taken into account. The purchase price is discounted for with depreciation, which can be calculated as costs per hour. On top of those financial expenses, interest has to be paid on the loan. These expenses are monthly overhead costs and will be accounted for when deciding the fares. The financing costs for trucks are given because the source gave the percentages for all the factors including finance. The financing costs for Plane and UCA are expected to be roughly equal to the depreciation costs (Boele, 2015).

5.3.1 UCA and truck

Trucks are on average six times cheaper than UCAs. It is therefore easy to say that, when comparing the costs, UCAs won't be able to compete with trucks.
The big advantage for UCAs however is the speed in which they can operate and the independency of infrastructure. While trucks may take a while to fully load up before leaving, and take twenty days of driving, it may take a month for the freight to arrive in the best of cases. The road network in Congo is in a very bad shape, so especially during the wet season the transport times vary with speeds lowering from 170km/day to 25 km/day. This leads to travel times higher than 100 days, making road transport impossible during the wet season.
UCAs on the other hand are much more flexible due to the lower capacity. This makes that the aircraft will reach its optimal loading capacity earlier, and reduces the time needed to load the freight. The average block time of a UCA is 4,5 hours, which makes UCAs at least 100 times faster than trucks. Comparing the costs with the transport times leads to the conclusion that UCAs are more expensive, but make that up with faster delivery times with lower variances.

5.3.2 UCA and barge

Barges can transport goods on average thirty times cheaper than UCAs. One drawback of using barges is the transportation time, which is 80 times slower than UCAs. An additional drawback is the large amount of cargo transported per haul. Barges will only depart when the trip can be profitable, which in practice means that the barge will only depart when it is completely full. Short trips to Mbandaka will be departing in a higher rate than long distance trips to Kisangani, since a trip to Kisangani always will come by, and thus stop at Mbandaka. The profitability of UCAs will thus increase with the distance flown. Because of the dependency of leaving Kinshasa on the amount of cargo on the barge, it is impossible to supply goods at given time intervals, increasing uncertainty and lowering the market value of barges.

5.3.3 UCA and plane

Currently, the most used way to transport emergency deliveries is to use airplanes. This is because of the long delivery times of the other ways of transportation. In the studied routes, a plane will take an average of 2,5 hours from point to point. Using a UCA instead of a manned airplane will take 4,5 hours, at a 20% cost saving.
The extra flying time of UCAs is only marginal, because the UCA will still be able to deliver goods directly when tasked to do so. The position of the UCA is even better when the higher uptime is considered, so the planes can schedule extra flights even when regular airplanes have reached their maximum availability.
The main differences in the cost structure are:

- Lower costs for aircrew due to the ability to fly multiple planes by the same operator
- Higher depreciation due to the higher initial investment on new airplane design
- Lower fuel costs due to lighter airframe and more efficient engines

6 How can a UCA be competitive on the long run?

In the current situation, medical supplies are delivered in trucks. The long delivery times mean that each hospital or field post needs to have a big safety stock. Using faster types of transport for the delivery of medicines will shorten the lead time, while the flexibility of UCA's can ensure rapid delivery to deal with urgent calls. In order to be able to respond quickly to these orders, it is necessary to have high uptimes for the aircraft. By designing the planes to fly long distances without maintenance, and the ability to repair failures on the spot by reading out the computer and changing software, the repair times will reduce with the travel times of mechanics. This means that a broken aircraft can be repaired earlier, while being quicker due to the low tech construction of the aircraft.

6.1 Aircraft characteristics

6.1.1 High starting capital

The current logistic sector in Congo consists of old trucks and boats, just like in the rest of Central Africa. Entering this market with new equipment is risky because of the high costs of development which have to be earned back in operating the UCAs. Starting a business here will therefore be well thought over, because the starting costs will have to be earned back over a long period of time (Hoeben, 2014).

6.1.2 Maintenance costs

The only way to deal with the high fixed costs is to lower the variable costs of flying. Because of the need to develop an entirely new aircraft, it is advisable to keep in mind that the aircraft will need to be able to fly in remote areas without much support. The aircraft must therefore be of a simple design where the chances of failures are small, and those failures can be repaired easily. If a broken aircraft can be fixed by non-schooled personnel, it isn't necessary to send mechanics to a broken aircraft. An extra benefit is that an easy maintainable airplane will be repaired much quicker, so the downtime will be reduced significantly. This will lead to a higher deployment rate, and thus divide the costs over more trips to make the costs per trip lower.

6.1.3 Low dependency of infrastructure

Because of the ability to start and land from short runways and the high range of the proposed UCA, it can reach destinations almost everywhere in the world without needing much infrastructure. The only asset needed in the destination area is a runway of at least 150 meters, from where the goods can be distributed to the recipients, and a local pilot to land the UCA.
In the event of floods or a natural disaster, roads can become impassable or destroyed. Normal ways of transportation will therefore have difficulties or are unable to reach the areas where the needs are the highest, delaying the delivery of lifesaving equipment and goods. Because UCAs only need infrastructure to start and land, they are ideal for delivering goods in those situations (Prent & Lugtig, 2012).

6.2 Operating characteristics

6.2.1 Absence of aircrew

The main selling point of unmanned aircraft is that there is no flight crew aboard the plane. Besides lowering the weight of the aircraft, this also means that flight crew rest is of much less importance than with manned aircraft. The only important factors for downtime left are loading and maintenance, so assuming that the aircraft is carrying enough fuel or is able to refuel at the destination airport, and that there is another freight waiting to be shipped in the return flight, the plane will be able to take of immediately after unloading and reloading the airplane.

This will mean that the aircraft is able to fly multiple routes without the need to change aircrews, and can thus fly over the rainforest for multiple days without needing to change aircrews in the home airport of Kinshasa.
The high possible uptime also means that the aircraft will be able to adapt to new missions, and use its flexibility to change its flying path to deliver emergency goods when and where needed. The only change of pilots will happen at the control center, and can happen when the plane is airborne, so no time will be lost in the process.

6.2.2 Inventory levels

Compared to trucks and barges, a UCA will have a lower transport capacity. This means that UCAs will have to make more flights, and the total transportation costs will be higher than with using regular transportation, which is a drawback of using UCAs. Flying with small loads does however have a big advantage for the end users by means of stock. This is explained with an example for flying medicines to hospitals:
In the case of high volume shipping, the times between deliveries can be large, so hospitals will have to have a huge safety stock of almost all types of medicine to assure that no shortages will occur. When shipping low volumes the planning horizon will be much shorter, so the certainty of the needs of the hospital will be more accurate. This will result in lower safety stocks, reducing the storage costs of hospitals from months to a week of supply.
In the case of the outbreak of deceases like Ebola, the demand for specific medicines emerges instantly. Because of the short transporting times of UCAs and the near direct availability, UCAs can quickly adapt to the new situation and deliver the right goods at the right place. This means that those specialist medicines can be stored at a central location instead of having to have inventory at every hospital, which further reduces costs (Hoeben, 2014), (Kremers, 2012).

6.3 Discussion

In this report, only the operational costs were taken into account. While this may be useful when choosing the best mode of transportation for an already established company, this is not the fact for Pedro.
The total costs will be higher than those calculated in this report, with overhead, housing, insurance and maintenance also entering the equation.

The values and costs for the UCA are uncertain due to the unavailability of aircraft. As a result of this, those values had to be guessed or estimated, and to be sure incorrect estimates wouldn't affect the comparison they are rounded up in the UCAs disadvantage. While the actual values may change, it will mostly be in favor for the UCA. Despite the large margin of error, UCAs still prove to have a solid business case.
The development and production costs per UCA are estimated at $10 million. This can prove to be a major setback when trying to set up the company. It is however possible to split development and production into separate costs models. This will require business partners and other buyers of the UCA, so the development costs can be divided over more planes, lowering the development costs, and thus the depreciation costs per flight hour. A decrease of $1 million in development and production costs will then result in an average decrease of depreciation costs per flight of $33.
Another possibility is to buy an aircraft developed by a third party like the Flyox (Singular Aircraft, 2016). This will be cheaper, but might not fulfill all specifications stated in this report.

7 Conclusion

Unmanned Cargo Aircraft can be used to transport goods from main entry ports to end users. While it is not yet possible to calculate all of the costs involved, it is possible to guess the characteristics of unmanned airplanes, and use these to guess operating costs. When the operating expenses of truck, plane and UCA are compared, it becomes clear that, while a UCA is much more expensive than a truck, it is also more reliable and much quicker, leading to the conclusion that UCAs should be deployed for fast deliveries. The common used method for delivering fast deliveries is by chartered airplanes. The higher utilization, lower fuel consumption and maintenance costs for UCAs make them cheaper to operate, while the only drawback is the slightly lower speed and thus a longer delivery-time.

Before UCAs can be used, a stable communications platform has to be set up, enabling the pilots to communicate with the airplanes and control all the statistics of the aircraft. Once that is done, a network has to be set up to ensure that the company is getting orders, and to maintain the aircraft to get them in perfect flying condition.

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Appendix A – Costs model Truck

The Nathan Study (Nathan, 2013) included four cost-statistics for trucking-routes through central Africa. These statistics consisted of fixed costs in $/day and variable costs in $/km. Both costs were further subdivided in cost segments by percentages of the total costs. In this study, the averages of those percentages will be taken as the cost structures for trucking.

Fixed Costs	staff	depreciation	finance	other		US$/day
Douala–N'Djaména	35	33	15	17		49
Douala–Bangui	28	26	25	21		73
Ngaoundéré–N'Djaména	36	35	0	29		22
Ngaoundéré–Moundou	38	34	1	27		21
Average	34,25	32	10,25	23,5		41,25

Variable Costs	fuel	tires	maintenance	bribes		US$/km
Douala–N'Djaména	60	17	10	13		1,31
Douala–Bangui	60	19	9	12		1,22
Ngaoundéré–N'Djaména	53	11	14	22		1,83
Ngaoundéré–Moundou	38	12	23	27		2,49
Average	52,75	14,75	14	18,5		1,7125

The trucing costs in this study are also the averages of the results from the Nathan-study, and are $41,25 $/day and $1,7125 $/km.

The study stated that the distribution of fixed and variable costs can be estimated at 30% and 70%. The percentages of all the cost elements is calculated as the average value of that cost element, multiplied by the percentage of the type of cost.
The total cost allocation is calculated by multiplying the number of days or kilometers of a trip by the costs per km or day and the above calculated section percentage. The fuel costs for the route from Kinshasa to Kisangani are therefore calculated as $15{,}45\ days \cdot 41{,}25\ {}^{\$}/_{day} \cdot (0{,}3 \cdot 34{,}25\%) = \$65{,}50$

	Section-percentage	percentage
Fixed costs (30%)		
staff	34,25	10,275
depreciation	32	9,6
finance	10,25	3,075
other	23,5	7,05
Variable costs (70%)		
fuel	52,75	36,925
tires	14,75	10,325
maintenance	14	9,8
bribes	18,5	12,95

Appendix B – Costs model Plane & UCA

The cost model used to calculate the operational costs for airplane and UCA is derived from the thesis of J.S.F. Hoeben (Hoeben, 2014), which takes all operational costs into account.
The model consists of two parts: the first one contains all transportation costs, while the latter consists of the cargo costs.

Transportation costs

Transportation costs are all costs incurred by the actual transportation of goods, and consist of airport usage, crew, fuel, maintenance and depreciation.
The model is built to calculate operating costs per week. In order to calculate the costs per flight, the flight frequency f, calculated as $\frac{weekly\ freight\ flow}{shipment\ volume}$ is set to $\frac{2\ tons}{2\ tons}$.

Airport usage

Taxiing and take of rights are factors of the airport usage charge. The most important factor is the Maximum Take Off Weight, which can be multiplied with the airport usage rate to calculate the airport usage costs.

$$C_{airport\ usage} = R_{airport} \cdot M_{MTOW} \cdot f$$

Aircrew

The aircrew costs are calculated as the aircrew cost per block hour times block hours. The block hours per flight are calculated as flight time + loading/refueling, where loading and refueling takes half an hour, making $t_{block} = t_{flight} + 0{,}5$

$$C_{aircrew} = A \cdot t_{block} \cdot f$$

Fuel

Fuel costs are calculated as price of fuel multiplied by the fuel consumption, with $FC = {}^{FC}/_{h} \cdot t_{block}$

$$C_{fuel} = P_{fuel} \cdot FC \cdot f$$

Aircraft depreciation

Aircraft are depreciated at a rate of 4% per year, which comes down to $\frac{4}{365} = 0{,}011\%$ per day, making the aircraft depreciation rate W=0,00011.
A plane can make multiple flights per day, so the depreciation costs need to be divided over those flights. When an aircraft is operational for U hours a day, the factor to take into account for each flight is $\frac{t_{block}}{U}$. Multiplying W and the usage factor with the price of the aircraft gives the depreciation costs.

$$C_{AC\ depreciation} = W \cdot \frac{t_{block} \cdot f}{U} \cdot P_{AC\ new}$$

Maintenance

Maintenance costs can be divided in labor and material costs, and airframe and engines. Because of the extra maintenance of engines, those labor and material costs occur more often and are therefore a factor 1,3 of the airframe costs.

$$C_{maintenance} = C_{lab,airframe} + C_{lab,engine} + C_{mat,airframe} + C_{mat,engine}$$
$$C_{lab,airframe} = MHR_{airframe} \cdot R_{labor} \cdot t_{block} \cdot f$$
$$C_{lab,engine} = 1{,}3 \cdot MHR_{engine} \cdot R_{labor} \cdot t_{block} \cdot f$$
$$C_{mat,airframe} = MAT_{airframe} \cdot t_{block} \cdot f$$
$$C_{mat,engine} = 1{,}3 \cdot MAT_{engine} \cdot t_{block} \cdot f$$

Cargo costs

Unlike trucks and barges, which can be loaded quickly and then leave, planes need to be perfectly loaded and balanced in order to be able to ensure a safe flight. These actions are known as Cargo Costs.

Warehousing costs

When goods are delivered to Kinshasa, there might not always be a plane or UCA ready to transport them to their destinations. When this happens, the goods will need to be stored on the airport, inflicting warehousing costs. The average waiting time is estimated at 2 hours, with a density ρ of 1 ton/m^3. The warehouse rent for food and medical supplies on the airport of Kinshasa is $0, in order to make it easier to ship humanitarian aid to Congo. This results in warehousing costs of $0, but to make future changes possible, these costs will still be inserted in the model.

$$C_{warehouse} = S \cdot \frac{Q_{AB}}{\rho} \cdot t_{wait}$$

Inventory costs

Airplanes are used to transport time-critical goods. The faster the delivery, the better, so a loss is occurring for taking too long to arrive at the destination. This effect is measured in the inventory costs. The constant k is determined from the commodity half time of perishables, $= \frac{\ln(2)}{t_{0,5}} = \frac{\ln(2)}{167h}$.

The value of the cargo at arrival in Kinshasa is estimated at $2000.

$$C_{inventory} = V_{cargo,0}\left(1 - e^{-k\cdot(t_{block}+t_{wait})}\right)$$

Cargo handling costs

The cargo needs to be tightly secured in the aircraft. In order to do so, the freight must be loaded and consolidated. The costs are proportional to the cargo volume, at loading/unloading costs of $50/m^3 and consolidation costs of $10/m^3.

$$C_{handling} = \frac{q_{AB}}{\rho}\left(H_{load/unload} + H_{consolidation}\right)$$

		unit		Beechcraft 1900D	UCA
A	aircrew costs per block hour	$/hour		312,5	62,5
dAB	flight leg distance between airports A and B	mile		route-specific	
f	flight frequency	flights/week		1	1
FC	fuel consumption	gallon		tflight * FC/h	
FC/h	fuel consumption per hour	gallon/h		95,84	31,94667
Hconsolidation	charge for the consolidation of cargo	$/m3	10		
Hload/unload	charge for loading and unloading cargo	$/m3	50		
k	Inventory loss factor	-	0,004151		
MATairframe	airframe and systems maintenance materials cost per block hour	$/hr		141,98	70,99
MATengine	engine maintenance materials cost per block hour	$/hr		141,98	70,99
MHRairframe	number of airframe and systems maintenance man-hours per block hour	-		1,986998	0,993499
MHRengine	number of engine maintenance hours per block hour	-		1,986998	0,993499
MMTOW	maximum takeoff weight	ton		7,764	6,162679
Pa/c new	aircraft new price	$		4995000	10000000
Pfuel	fuel price	$/gallon	2,82		
Q	shipment volume	ton		2	2
qAB	freight flow between airports A and B	ton/week	2		
Rairport	airport charge rate	$/tonMTOW	4		
Rlabor	aircraft maintenance labor rate per man-hour	$/hr		251,27	251,27
ρ	commodity density	ton/m3	1		
S	warehouse rent	$/m3	0		
tblock	block time	hour		tflight + 0,5	
tflight	Flight time	h		dAB * Vc	
twait	average cargo waiting time before transport	hour	2		
t0.5	commodity half-time	hour	167		
U	average utilization	hr/day		8	14
Vc	airplane cruise speed	mile/h		310	160
Vcargo,0	value of the cargo right before arrival at the airport	$	2000		
W	aircraft depreciation rate (25 years)	%/day	0,00011		

Appendix C – UCA characteristics

The characteristics of the UCA in this thesis result in a number of requirements for the design of the aircraft. They are stated below in this appendix.

Technology

- Payload of 2000 kg
- No cockpit
- Pilot is controlling 5 planes
- No pressure cabin
- Strong, lightweight, windowless structure
- Make use of existing, reliable engines and technology
- Propeller-driven
- Air speed of 160 mile per hour (257 km/h)
- Possibility to transport entire system of planes and flight control units in shipping containers
- Easy and cheap manufacturing

User-friendliness

- Able to land on unpaved runways
- Maximum length of runways is 150 meters
- Easy, unaided unloading of cargo
- Range of 3000 km
- Utilization rate of 14 hours per day