UNMANNED CARGO AIRCRAFT – THE STRUCTURED DEVELOPMENT OF A DEPLOYMENT AREA ASSESSMENT INSTRUMENT

Bachelor's Thesis University of Twente Enschede

ABSTRACT

Unmanned, so unloved? "UCA have proven to be able to operate as a beneficial mode between two smaller regions in China and Germany that are currently not directly connected" (van Groningen, 2017). This research answers the question why an area is or is not viable for using large unmanned cargo aircraft

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Colophon

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Preface

The report in front of you is the result of seven months of research conducted at the University of Twente on behalf of the Platform Unmanned Cargo Aircraft. The research has been done to complete the bachelor programme Industrial Engineering and Management at the University of Twente. Finishing this assignment represents the end of my bachelor programme at the University of Twente.

The realization of this research has been done with help of various people and organisations. I would like to thank some of these people in personal.

About three and a halve years ago I first met dr. J.M.G. Heerkens. At that moment he ignited me with his enormous enthusiasm and passion about unmanned aviation. I would like to thank dr. J.M.G. Heerkens for giving me the opportunity to conduct this research in the unmanned aviation sector. I would also like to thank dr. J.M.G. Heerkens and dr. B. Roorda for their critical but fair view on this report. Unfortunately, dr. J.M.G. Heerkens had to give up his role as main supervisor due to medical reasons. I am very grateful to dr. B. Roorda for his willingness to take over this role. I would like to thank dr. P.C. Schuur for his role as second supervisor. Although his supervision was initially not planned, his feedback has been of great value.

Subsequently, I would also like to thank two members of the Platform Unmanned Cargo Aircraft in their role of interviewee. They steered this research in a direction that would not have been possible to reach with literature alone. They showed me that not all available knowledge has been recorded.

And last but not least I would like to thank my family and friends. My parents and sister in particular; your support during my entire study has been priceless.

There is only one thing left for me to say; I wish everyone a lot of reading pleasure.

Joop Johan Jeffrey Wolters

Deventer, July 2019

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Abstract

In this research a method is developed that helps its users assessing the attractiveness of an area regarding the deployment of Unmanned Cargo Aircraft (UCA). International market selection strategies used by companies as well as reports published by the Platform Unmanned Cargo Aircraft (PUCA) have been conducted. Research about UCA is still scarce. For this reason, existing knowledge has been supplemented with the knowledge from two experts within the field of UCA deployment. Literature combined with expert knowledge resulted in a list of factors that influence the attractiveness of an area. To keep the overview, a causal model has been developed with those factors that have a causal relationship with the main variable area attractiveness. The requirements for the existence of a causal relationship were provided by the book Geen Probleem (2012).

One of the requirements for the instrument set by the Platform Unmanned Cargo Aircraft was that the method should be generally applicable. To do so, the analytical hierarchy process (AHP) has been used to reflect one's indicator preference. Users must compare sets of two indicators after which the relative importance per factor is calculated according to the AHP approach. This relative importance per factor is called the eigenvector. In order to be able to assign a score for each area per factor, an adapted version of the GIS-based Landscape Appreciation Model (GLAM) has been used. This model uses positive and negative indicators that are assigned a score at the interval between 0 and 4. Scores can only be natural numbers. To ensure that the model is also applicable in this study, the model will be expanded with selection indicators that either can be assigned a score 0 or 1. The final score per area is calculated by multiplying the relative importance per factor with the area score for that factor. Positive scores are added up after which the scores for negative indicators will be subtracted from the this. The remaining score will be multiplied by the score for each selection indicator. This means that if an area does not meet a selection indicator and thus receives a score zero for this indicator, that the total score for that area also equals zero. For a given moment in time, the score of an area per factor is fixed. However, it is not likely to assume that every area has the same score on each criterion at a later point in time. For this reason, the source (often a database) from which the scores were derived, are described.

The factors, the AHP and the adapted version of the GLAM model have been implemented in Microsoft Excel. Microsoft Excel is ideally suited because a user can perform the pair wise comparisons relatively easy, after which they are automatically calculated to a relative importance per factor. This relative importance together with the score of the areas on the factors are used to calculate the final score per area.

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The Research

Goal

The goal of this research is to develop an instrument that assesses the extent to which an area is viable for unmanned cargo aircraft (UCA) deployment.

Problem statement

First of all, it is necessary to mention that the problem has been brought forward by the Platform Unmanned Cargo Aircraft (PUCA). This platform aims at facilitating the development of unmanned cargo aircraft (UCA). PUCA also aims at letting its members play a meaningful and profitable role in this development (PUCA, 2013a). The chairman of this platform encountered the following core problem: The absence of an instrument that assesses the viability of an area regarding UCA deployment in that area. This problem may exist due to the fact that it is not known which factors influence the variable attractiveness. The research question below therefore tries to find an answer to this.

How can we measure the attractiveness of a location for unmanned cargo aircraft deployment in that location?

Research questions

To be able to solve the main research question a number of sub questions have been developed. Each of the sub questions addresses a different aspect of the solution of the main research question.

[1] *According to the literature, which factors influence the attractiveness of an area?*

The goal of this sub question is to get insight into what factors have the ability to increase or decrease the viability of an area for unmanned cargo aircraft deployment. The assumption is made that attractiveness can be divided into different categories. The answer to this sub research question contributes to the solution of the core problem in the following way.

- An overview of the categories that determine area attractiveness
- A number of factors per category that influence the attractiveness of an area.

[2] *What are the most important characteristics of unmanned cargo aircraft?*

After the attractiveness factors have been determined, it is necessary to go deeper into the characteristics of UCA. In particular it is helpful to know what properties distinguish these aircraft from other modes of transport. The goal of this research question is to identify characteristics that make UCA ideally suited to use in certain areas.

[3] *How can the quality of the list be determined?*

[3,1] How can the correctness of the list be established?

[3,2] How can the double-counts be determined?

[3,3] How can the consistency be determined?

The purpose of this question is to verify the validity of the instrument input. The instrument has to measure the attractiveness of an area. Without a valid input the instrument will never provide valid results regardless of whether the instrument itself is valid or not. The answer to this research question is result4 in:

- An elimination of the double counts
- Substantiation of the completeness
- Discussion on the consistency of the factors provided.

[4] *What factors influence the area attractiveness according to members of PUCA?*

The goal of this research question is to complement and/or verify the list composed in research questions [1]. Members of PUCA represent possible end users of the instrument and are expected to be involved in the development of UCA. These members will provide an overview of what factors they think are beneficial for the viability of an area. The answer to this research question can possibly result in:

- An addition to the existing list of factors
- The removal of a number of factors that were mentioned in the literature but that are not of interest to end users

Deliverables

The main deliverable of this research is an instrument which can be used to score any possible location on its attractiveness regarding unmanned aircraft deployment. Next to this instrument, this research provides a case example which users can use as a guideline for scoring their own locations.

Research design

This research about assessing area viability for unmanned cargo aircraft deployment is descriptive as well as qualitative of nature. A literature research is conducted to find out what is already known about this topic. This is done by answering two sub research questions ([1], [2]). Qualitative research is done by conducting interviews with experts in the field of UCA deployment. The main goal of these interviews is to supplement and/or verify the information found in the literature. Respondents have been recruited among members of the Platform Unmanned Cargo Aircraft (PUCA). Via Dr. J.M.G. Heerkens two members have been selected. The respondents that have been selected are actively involved with the development and deployment of UCA. The factors gathered from the literature and through interviews will then be applied in an instrument. Since it is not likely that all users value the same factors with the same importance, the instrument will provide the possibility to give weights to the different factors.

Report structure

The structure of the report is such that the next chapter describes the theoretical framework. Section [1.0], [1.1] and [1.2] describe how organisation select their overseas business locations. Section [1.3] introduces the Four-stage selection model. This selection model serves as a guideline for identifying the area attractiveness factors which is done through sections [1.3.1] up till section [1.3.7]. Subsequent, section [1.4] describes the causal relationship model that has been developed using the indicators found in previous sections. Chapter one concludes with a description of the most important UCA characteristics.

Chapter two describes how the research has been conducted. Section [2.1] describes the data collection methods. Section [2.2] describes the inclusion- and exclusion criteria used for the data collection. Whereas the research process, analysis of the data, development of the instrument and a check of the validity and reliability is described in sections [2.3] up till [2.6] respectively.

Chapter three is devoted to describing the interviews and the main conclusions that have emerged from these. The added value of chapter three is a list of factors that are not mentioned in the literature. Section [3.3] concludes chapter three by checking the consistency, completeness and correctness of the list of factors that have been gathered in chapters one and three.

Chapter four combines all the previous chapters into a detailed description of the development of the instrument. The basis of the instrument is formed by the analytical hierarchy process which is described in section [4.1]. Section [4.1.1] describes the first step of the AHP, namely filling in the pair wise comparison matrix. A subdivision of the factors is derived from the GIS-based Landscape Appreciation model. An adjustment of this model has led to a subdivision of the factors into positive, negative and selection factors. The description of this can be found in section [4.2]. Section [4.2.1] describes the preference levels per indicator group. Section [4.3] and the corresponding subsections describe the operationalisation of the positive, selection and negative indicators respectively. Section [4.4] briefly describes the most important guidelines on how to use the instrument whereas section [4.5] describes the most important limitations of using the model.

Chapter five provides a case study in which the instrument, developed in chapter four, is applied to Karlstad, a middle size city in Sweden. The chapter explains how the final score for a location is determined.

Chapter six answers the research questions introduced prior to chapter one. These answers are based on chapters one up till five.

Chapter seven describes recommendations for future research. It also describes both the technical and non-technical changes that should be made to the instrument before it could be used. Section [6.4] describes how to proceed from this point in time.

The final chapter, chapter eight, provides an overview of the sources used in this research.

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1. Theoretical framework

This chapter explains current existing academic perspectives available about my research. It identifies the factors that are used to indicate the attractiveness of an area regarding the deployment of any mode of transportation. After this has been done, the most important UCA characteristics are mapped.

1.0 Area attractiveness indicators

This literature review starts by describing a model used by companies to select their international export markets. However, this model describes international *markets* whereas this research is focussed at the *areas* in which these markets are located. A relation between these two objects has to be found using existing literature. The relation between markets and their specific locations is described in section [1.3]. Miečinskienėa *et al.* (2013) propose a four-stage market selection model. In its current form this model is used by organisations to select export markets for their products. The model is altered to make it applicable for determining the attractiveness of an area. In its current form, the model is used to eliminate markets that do not meet specific criteria, whereas in this research a model is needed to assess the attractiveness of areas by scoring them on criteria which are extracted from the literature. Therefore, two major changes will be made to the existing model: [1] Elimination criteria will be replaced by criteria which can be used to assess the attractiveness of an area and [2] new conjunction criteria will be added to eliminate areas that do not require to be scored on their attractiveness. Once the model has been adjusted, numerous factors per category of attractiveness criteria will be developed using literature about transportation systems as well as reports from former students published by the Platform Unmanned Cargo Aircraft.

The first section of the literature revision addresses the following research question:

[1] *According to the literature, which factors influence the attractiveness of an area?*

This research question suggests that a list of factors will be described. To my best knowledge, there has been no research conducted about which factors influence the viability of an area regarding transportation with unmanned cargo aircraft. Thus, it is logical to assume that literature will not describe many (if any) areal factors beneficial for deploying unmanned cargo aircraft. For this reason, factors playing a role in selecting areas concerning other modes of transport such as manned cargo aircraft or sea shipping have been reviewed.

Stefancic, Krobot and Hrzenjak (2006) researched policy instruments that could help reduce or eliminate transportation problems. According to Stefancic *et al.* (2006), the wider implications of deploying a new mode of transport have to be considered. They emphasize that the objectives needed to achieve a solution can derived from the desired solution. In this research the desired solution or rather the desired situation is described within the vision of the Platform Unmanned Cargo Aircraft.

> *"Creating a dense, adaptable network for moving goods so that each small company or even individual can become his or her own shipper" (PUCA, 2012).*

Stefancic *et al.* (2006) argue that every vision can be realized through fulfilling a number of more detailed policy objectives. Fulfilling each objective brings one a small step closer to reaching the desired solution. However, the vision above does not explain much about the deployment of UCA itself. Instead it raises the question; how can UCA help in fulfilling this objective? The answers to this question identify the wider implications that should be taken into consideration when deploying UCA. Stefancic *et al.* (2006) describe seven implications needed for successful deployment of any mode of transport. [1] Economic efficiency, [2] safety, [3] accessibility, [4] sustainability, [5] economic regeneration, [6] financing, and [7] practicability. To find out the relevance of these seven categories, they will be compared to the categories of the Four-stage selection model proposed in section [1.3].

It can be concluded that when a new means of transportation is used, seven different categories of factors should be taken into account.

1.1 Firm location decision

Stefancic *et al.* (2006) described the categories of factors that should be taken into account when deploying a new mode of transportation. However, before any new mode of transportation can be deployed, it is necessary to know where it should be deployed. To be able to do this, both the geographic characteristics of a location and the market characteristics of the market in that location have to be considered. Porter (2008) describes the market structure as one of the main determinants for company success in that market. In addition, Porter (1992) described five forces that determine the success of a product within an industry: [1] customers, [2] suppliers, [3] substitution products, [4] potential vendors and [5] competition between current vendors. These five factors determine the long-term success of a new product within a specific industry (Gleissner, Helm & Kreiter, 2013). From these factors only the first, customers, and the last one, competition are relevant for this research. In the current situation, only small initiatives exist in the development of UCA. Consequently, no competition exists between different UCA suppliers (yet). However, UCA can encounter competition from other means of transport in the same area.

1.1.1 Customers

Prent (2013) researched the market for UCA without exactly calculating the expected demand for UCA. Prent (2013) concluded that the market for UCA has to meet certain requirements.

1.1.2 Competition

Since UCA cannot compete with other modes of transport in terms of cost, the following conjunction criteria exist (Prent, 2103). Other, cheaper modes of air transport cannot be present for UCA to be deployed successfully. However, UCA can compete in a number of special cases. UCA are able to compete when the goods that have to be transported decrease in quality over time. In other words, fast transportation is required due to the goods being perishable (van Groningen, 2017) High transportation cost can be overcome in case UCA transport goods with high added value (van Groningen, 2017).

Possible UCA deployment areas are thus areas in which no competition exists or areas in which the competition can be overcome due to certain characteristics that the goods possess in these areas.

1.2 IMS

International market selection (IMS) reflects the choice firms make in internationalizing their business processes (O'Farrell & Wood, 1994). Internal market selection extends Porter's firm location decision [1.1], by placing the decision into a wider context. The choice for an external market is not solely based on the characteristics of that market. Instead, the choice is based on determinants as (O'Farrell & Wood, 1994): [1] market size, [2] geographic proximity, [3] cultural distance, [4] country risk, [5] intensity of competition, [6] market similarity, [7] size, and [8] international location choice.

In addition to the eight IMS determinants as described by O'Farrell and Wood (1994), Miečinskienėa, Stasytytėa, and Kazlauskaitė (2014) claim that the market selection step is of very high importance for those companies that are planning to export their products to foreign markets. Miečinskienėa *et al.* (2014) propose that the assessment of the attractiveness of a market should be done using a model that evaluates certain factors. In their research, Miečinskienėa *et al.* (2014) mention numerous authors who all have different viewpoints on how to correctly obtain these variables. Kontinen and Ojala (2012) support the findings described by O'Farrell and Wood (1994). Other authors elaborate on a so-called screening method. As the name already reveals, this method uses easy-to-find factors to screen possible export areas (Časas, 2008; Papadopoulos & Martin, 2011). These factors include: [1] economic factors, [2] political climate, [3] geographical factors, [4] cultural environment, [5] technological factors and [6] foreign trade policies.

Because these six categories largely overlap with the seven transportation objectives described by Stefancic *et al.* (2006), they will serve as the main categories of area attractiveness factors. The next section describes original four-stage selection model and the adjustments made to it. After that, the literature revision describes factors within the six categories of the model.

1.3 Four-stage selection model

Miečinskienėa *et al.* (2014) propose a four-stage market selection model. The market selection procedure (Fig. 1) describes four separate stages every companies has to go through in selecting a viable export market.

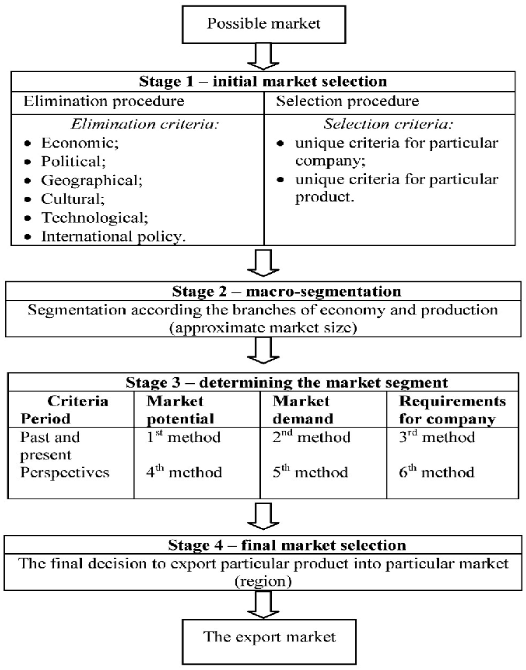


Figure 1: Export market selection procedure (Source: Algita Miečinskienė et al. / Procedia - Social and Behavioral Sciences 110 (2014) 1166 – 1175)

The original four-stage selection model does not fit the purpose of this research. The purpose of this research is to develop an instrument with which the user can assess the attractiveness of any location regarding the deployment of UCA in that location. Stage one from the four-stage selection model will be used to assess the attractiveness of the areas in which UCA are to be deployed. The current stage one describes elimination criteria. Elimination criteria are used by firms to eliminate markets that do not meet these criteria. Since the model in Figure 1 is about market selection and this research about area selection, a gap exist between what is available and what is needed. This gap is filled by Gleissner *et al.* (2013) and Rodrigue *et al.* (2017). Gleissner *et al.* (2013) claim that market attractiveness is an external factor and therefore cannot be influenced by the companies who are in that market. Rodrigue *et al.* (2017) describe the relation between a market and its location by arguing that each market, in which any form of economic activity takes place, is connected to a specific location. By combining these two statements it is thus possible to interpret area attractiveness as an external factor that cannot be influenced by (transportation) companies.

Before the four-stage selection model can be used, it is necessary to adjust the model. Currently, stage one describes criteria which can be used to eliminate specific areas. However, this research is aimed at determining the attractiveness of areas; It serves as a tool in making well-informed decisions about what area to select by providing the attractiveness of that area based on the preferences of the user. Thus, stage one of the model does not describe *elimination criteria* but rather elaborates on *attractiveness factors.* The six categories that currently serve as elimination criteria will be attractiveness assessment factors in the adjusted model. Secondly, new conjunction criteria will be added to the model. Conjunction criteria consist of those factors whose value is not important. What is important with these factors is that they are met. The adjusted model is represented in Figure 2.

Stage 1 – initial area selection	
Attractiveness criteria categories: • Economic; • Political; • Geographical; • Cultural; • Technological; • International policy	*Elimination factors:* • Absence of conventional air freight; • Overcoming higher transportation cost;

Figure 2: Adjusted Four-stage selection model

Kreutzer (2006) and Hofbauer *et al.* (2009) describe a term that encompasses four of the criteria categories from phase one of the four-stage selection model. They define macro environment as large environmental factors that influence companies indirectly. Macro environment consists of four categories: [1] economy (*Economic criteria)*, [2] society (*Cultural criteria)*, [3] technologies (*Technological criteria)*, and [4] and law/politics (*political criteria*) (Kreutzer, (2006); Hofbauer *et al.*, 2009). The most well-known approach for defining the factors within these four macro-environmental categories is the PEST approach by Pfaff (2004). The PEST analysis is a strategic tool for understanding different aspects of a market (Pfaff, 2004). Applying this approach results in a number of indicators for each of the four dimensions of macro environment. However, the PEST-approach only describes factors for four of the six categories in Figure 2. An additional method is needed to identify the factors of the remaining two categories, namely geographical factors and legal factors.

1.3.1 Political area attractiveness

The first dimension of the PEST approach are the factors that are classified into the political category. These factors describe the way in which the government intervenes in the economy. Political factors are area specific factors and include political stability, in/export regulations, tax policies and trade restrictions (Birnleitner, 2014). Rodrigue *et al.* (2006b) describe a subdomain of regulations, namely safety. Factors indicating if this safety objective has been met, include personal injury accidents and population insecurity. In addition to these two general transportation safety concerns, Collins (2017) describes the fear of criminals using the unmanned aviation technology for menacing purposes. Cho (2014) mentions the possibility of terrorist intercepting information being transferred from UCA to ground and vice versa. However, these risks are being minimized by developing security systems for drones. For example, a system has been developed which lets drones only obey orders given from a certain GPS location (Collins, 2017).

Stefancic *et al.* (2006) describe the relationship between an area and the perceived safety level. The population insecurity is higher in densely populated areas then it is when unmanned cargo aircraft only fly over large bodies of water.

The most important political factors that influence the attractiveness of a location are the political stability in that location, in/export regulation that hold for that location and the population density in that location. Population density is related to the extent to which inhabitants feel insecure and thus is part of the safety subdomain of regulations.

1.3.2 Economical area attractiveness

The second category of criteria for which the PEST-approach describes factors are the economic criteria. Important economic indicators include economic growth, supply and demand rates and competition factors (Kew *et al.*, 2005). Assessing area attractiveness for transportation systems requires additional indicators (Stefancic *et al.,* 2006). Economically justifiable transportation of goods within an area depends on the presence and/or absence of many factors. Porter (1980) describes the market structure as one of the main determinants for company success in that market. In addition, Porter (2008) described five forces that determine the success of a product within an industry. For UCA to be successful within a region, customers have to be present while at the same time cheaper and/or slower competitors must be absent (Prent, 2013). Within the context of this research, customers are defined as those parties who are willing to use UCA to transport their goods with. Van Groningen (2017) mentions an important characteristic that the customers need to possess. Van Groningen (2017) researched that UCA are designed in such way that they are suitable to transport high-value, time-sensitive cargo. According to The World Bank (2009), high value consumer goods travel from developed countries to developing countries, whereas flowers, electronical devices (and their parts), fresh fruits and vegetables travel from developing countries to developed countries. Besides the presence of high-time value goods, literature does not describe factors that directly indicate the economical attractiveness of a location. Baron (2010) provides the solution to this by subdividing economical area attractiveness into economic-, time-, distance-, energy- and cost efficiency.

Economic efficiency

Transportation plays a key role in the development of economies and in the development of the welfare of populations (Rodrigue *et al.*, 2006b). Economic efficiency of transportation systems leads to opportunities, both economic and social, as well as improving the general economy (Rodrigue *et al.*, 2006b). Economic efficiency is defined as the optimal allocation of every resource such that each individual or entity is served optimally while the amount of waste is minimized (Investopedia, 2006). Striving for economic efficiency can result in two types of economic impacts: direct and indirect (Rodrigue *et al.*, 2006b). Direct economic impact of transportation leads to transportation enabling larger markets to be served and enabling to save time and cost. Indirect economic impact relates to the economic multiplier effect which causes the price of products to drop while increasing their variety. Consequently, direct transportation impact can be translated into an area being connected with surrounding areas or not whereas indirect impact is indicated by the product prices.

Thus, whether a location is economic efficient or not is indicated by the product prices in that location as well as the fact that the location is or is not connected to surrounding locations.

Time efficiency

Freight can be transported by numerous modes of transport including truck, train, ship, conventional cargo aircraft and unmanned cargo aircraft. A mode of transport is considered time efficient if the travel time is the shortest compared to transport using other modes of transport (Baron, 2010). In this case travel time is measured as the total time it takes to travel from origin to destination (Baron, 2010). Speed of unmanned cargo delivery can be a great advantage (de Lange, Gelauff &

Gordijn, 2017; Prent, 2013). Transport can be faster since UCA can create direct connections that did not exist before (Prent, 2013). In addition, UCA can transport low volumes efficiently (PUCA, 2013a). Consequently, areas between which there is no direct connection currently available may be interesting for UCA deployment.

Thus, whether a location is time efficient or not depends on the existing connections with surrounding locations. If a location already has fast transportation connections with surrounding locations, then UCA are likely to be not time efficient.

Distance efficiency

The decision of what mode of transport to use is not only based on the transport time (Trade Logistics, 2015). The distance over which the goods must be transported also plays a significant role in this decision. A destination overseas will eliminate road and rail as modes of transport. For trips below the 300 kilometres the car is the most preferred mode of transport (Baron, 2010). The minimal transportation distance for UCA, to be economically efficient, has been researched by Prent (2013). He concluded that the distance between two locations must be bigger than limit below which a product can be transported cheaper by other modes of transport. In developing countries this minimum distance is determined at approximately 290 kilometres whereas in developed countries the distance over which cargo is transported by UCA at least has to be 570 kilometres. From this it can be concluded that it is easier to deploy UCA in developing countries then it is to deploy them in developed countries. An additional indicator is formed by the quality of the infrastructure present. There could be routes which are shorter than the limits described above but inaccessible by land transportation. In this case UCA are the means of transport par excellence since they are able to fly over the infrastructure. The same holds true for areas with much height differences. The distance may be shorter than the ones on which UCA become economically efficient, however "due to the height differences it can be extremely expensive to transport goods using road transport" (Heerkens, 2019).

Thus, whether or not a location is distance efficient depends on multiple factors. A minimum distance must be bridged in which a distinction is made between developed and developing areas. The quality of the infrastructure present and the height difference in the area also determine whether a location is distance efficient or not.

Energy efficiency

Energy efficiency can be increased in two ways (Baron, 2010). The first way is to increase the output for the same level of energy input. The second way is to reduce the energy input for a given level of output. Energy use in freight transportation is measured using the Specific Fuel Consumption (Gellings & Parmenter, 2009). The specific fuel consumption measures the number of grams of fuel required to produce a power of 1 kilowatt for the duration of one hour (Hallsten, 2009). The absence of a crew implies no restriction on the duty length. This means that UCA are able to fly at speeds optimized for fuel efficiency (PUCA, 2013a). Efficient use of energy is a characteristic of unmanned cargo aircraft. The only link between the deployment area of UCA and their energy efficiency are the fuel prices. When comparing UCA with other modes of transport, areas with high fuel prices are more attractive to deploy UCA in. This is the case because UCA are designed to be more fuel efficient than any other mode of transport (PUCA, 2013a).

In conclusion, specific fuel consumption indicates to what extent UCA are energy efficient. Due to the absence of a crew, UCA can fly at lower speeds optimised for fuel savings.

Cost efficiency

Simply put, transportation of freight requires the use of resources like infrastructure, labor, equipment and fuel (Transportation Economic Trends, 2016). Transportation cost equals the use of these resources. According to the Cambridge Dictionary cost efficiency is defined as 'a way of saving money or spending less money'. Since cost equals the use of resources, cost efficiency can be seen as transporting freight using less resources or transporting more freight using the same amount of resources (Baron, 2010). Norwood and Casey (2002) identified four indicators that measure the economic aspects and expected earnings of any transportation system.

Transportation cost. The price users have to pay in order to use the transportation network. UCA transportation prices have been researched by Prent and Lugtig (2012). They divided UCA transportation cost into direct- and indirect cost, after which direct cost are subdivided into fixed cost and variable cost. Transportation cost are fixed for unmanned cargo aircraft, assuming that the route and type of cargo is known. It is more interesting to look at the transportation costs compared to other means of transport. The question to ask here is: given the freight to be transported on a specific route, which of the available means of transportation is the cheapest?

Transportation productivity. Transportation productivity overlaps with the energy efficiency as described by Baron (2010). It reflects how much output is derived for any level of input. For example, transportation productivity measures how many loads can be transported for a given labour cost budget. Transportation productivity is a relevant economic indicator because it reflects the level of return on investment (ROI) which is the most commonly used financial performance measure (Rodrigue, 2017; Corporate Finance Institute, 2015).

Logistics cost. Logistics cost is an extension of the costs included in the transportation cost. Logistics cost not only include the costs for transporting cargo but also additional costs like warehousing, space, packaging, loading, offloading, airport fees, security, materials handling, etc. UCA are designed in such way that they can operate requiring only small logistics cost. The design of UCA enables much logistic tasks, on- and off-loading for example, to be automated.

Transport capacity utilization. Transport capacity utilization reflects on how the capacity of the transportation system is divided. It measures the amount of transportation vehicles (modal capacity) in relation to the amount of cargo handling units (intermodal capacity) (Rodrigue, 2017). Transportation capacity utilization is not area dependent and will therefore not be threated any further.

According to Heerkens (2018), the transportation cost per kilogram of freight decrease when freight is transported on an increasingly large scale. The unmanned cargo aircraft covered in this research have a payload of 2 to 20 tons[1]. Yet these smaller unmanned cargo planes can outweigh higher transportation cost due to a number of factors as described by PUCA (2011). These factors cause unmanned cargo aircraft to be cost efficient since they cut on expenses that form a large share in conventional freight transport (Transportation Economic Trends, 2016). Prent (2013) mentions the factors that enable UCA to be cost efficient.

According to Prent (2013), air cargo is prohibitively expensive compared with belly freight, ground transport or sea shipping. UCA cannot compete with belly freight in terms of cost (Prent, 2013). However, UCA are able to save resources and/or use less resources due to various reasons; UCA design which results in route flexibility, flow and load optimization, optimized cargo handling, optimized cruise speed etc. Additionally, smart process designs can further improve the cost efficiency by reducing the number of resources needed. For example, automated cargo loading systems can reduce the number of ground staff needed. How the design of UCA lead to these savings is discussed in section [1.5].

In conclusion, the economical attractiveness of a location cannot be directly indicated with factors. Instead the economical attractiveness is subdivided into categories for which indicators have been identified. These indicators together represent the economical attractiveness of a location.

1.3.3 Societal area attractiveness

A third category for which the PEST-approach identifies factors, is the socio-cultural or societal category. Important societal factors include demographic trends, income distribution, lifestyle, quality of life and social equity (kew *et al.*, 2005). The societal impact of a new transportation system has been researched often (Rodrigue *et al.*, 2006b). The social dimension of transport is focussed at improving the standards of living and the quality of live (Rodrigue *et al.*, 2006b). This objective can be fulfilled by unlocking the economic potential of a region. UCA can help unlocking these potentials by supplying goods needed for using local resources (Koopman, 2017). It differs per region whether or not the economic potential already has been unlocked. Areas with a locked economic potential are usually not served by other means of transport (Koopman, 2017). This implies that the absence of belly freight or conventional cargo networks indicate a locked economic potential. IATA (2018) add additional indicators of areas with a locked economic potential. They argue that

[1] For comparison the Boeing 777F has a payload of 102 000 tons over a range of 9000km (https://www.upinthesky.nl/2017/12/11/turkish-komt-nieuwe-777f-naar-nederland/)

these areas are often geographically remote resulting in high product prices.

Thus, the social dimension of a transportation system focusses at improving the quality of life. UCA can increase the quality of life by unlocking the economic potential of a region. Locked economic potentials are identified through high product prices and the often-remote geographic locations.

1.3.4 Technological

The last category of macro-environmental factors according to the PEST-approach is the technological category. Important technological indicators include research and development, speed of technology development and new innovations. All the technology needed to accommodate UCA is already available. Accommodating UCA requires facilitations like landing and take-off systems, training staff and ground controllers.

Now that the factors for the four macro environmental dimensions have been indicated, still the factors for the remaining two dimensions have to be indicated. The PEST approach has been supplemented in the mid-nineties (Birnleitner, 2014). By adding the letters E and L, the Environmental as well as the Legal dimension can also be included in the PEST-approach. By adding these two dimensions to the PEST approach, all of the six categories from the adjusted version of the four-stage selection model (Fig. 2) have been discussed.

1.3.5 Environmental area attractiveness

Within the environmental dimension, Rodrigue *et al.* (2006b) distinguish between economic efficiency, environmental impact and social equity. Economic efficiency has already been discussed in section [1.3.2] whereas environmental impact and social equity will be described below.

Environmental impact

As already indicated in section [1.3.2], transportation fulfils a key role in the energy transition. Because transport takes place on a large, worldwide scale, consequences like noise- and air pollution, public health and air quality are of great importance (Rodrigue *et al.*, 2006b). The latter is defined by Stefancic *et al.* (2006) as the environmental impact; management provisions of freight transport should be focussed on reducing the environmental footprint. Indicators for this objective are: noise pollution and all sorts of emissions (Rodrigue *et al.*, 2006b; Stefancic *et al.*, 2006). Noise pollution can be harmful by impacting human or animal life (Environmental pollution centers, 2017). When noise pollution is correlated with population density a level of exposure to noise pollution can be calculated. According to the Environmental pollution centers (2017), noise pollution will be less when one is as far removed from heavy traffic as possible. Using UCA in remote areas like rainforests or desserts is thus likely to cause less noise pollution then when UCA are deployed above big cities.

Social equity

Social equity is referred to as the equitable distribution of transportation impacts, both beneficial impacts as well as disadvantages and costs (Litman, 2012). According to Litman and Burwell (2006), social equity is a pre-condition for economic balance, social objectives and environmental objectives. This statement is substantiated by Rodrigue (2017) who subdivides sustainability into economic efficiency, environmental impact and social equity. The literature provides no clear indicators which can be used to measure if an area meets the need for social equity. Rather, literature mentions social equity and accessibility in the same breath. Equity is described as a transportation network being equally accessible to anyone (Di Commo & Shiftan, 2017). In this research social equity is treated as a subdomain of the environmental dimension of transportation networks. Indicators of social equity are provided by Di Commo and Shiftan (2017). They describe three types of social equity indicators. From these indicators, only the measure that addresses the extent to which transport is made accessible is relevant within this research. Accessibility to key activities of transportation is indicated by (Di Commo & Shiftan, 2017): [1] isochrones measures of accessibility. This measure describes the extent to which the transportation network is accessible within, for example, 30 or 40 minutes of travel time. [2] Gravity-based measures for accessibility. The further the transportation from a potential user, the lower the accessibility value becomes.

Thus, the environmental attractiveness of a location depends on the environmental footprint which is indicated by the pollution caused. In addition, environmental attractiveness is indicated by the extent to which the transportation system is equally accessible for everyone. Indicators for the accessibility are focussed on the distance and time that a person has to travel in order to use the means of transport. Thus, in this research it represents the distance the freight has to travel to reach the UCA and the time required for this.

1.3.6 Legal area accessibility

Unlike political factors, the legal factors do not focus on the economic aspects of transporting goods. The legal factors are aimed at how companies operate and the demand for its products. In the context of this research legal factors partly determine the accessibility of an area. Besides the legal part, accessibility is also determined by the geographical characteristics of an area. Di Commo and Shiftan (2017) already introduced two measures for the geographical accessibility. Section [1.3.7] elaborates in greater detail on the geographical accessibility of a location.

Whether a location is legally accessible or not depends on a number of factors for that location. AIA (2018) concludes that cargo aircraft operating above remote areas or large bodies of water are the most likely to become fully autonomous in the near future. Remote areas and large bodies of water both argue a low population density. A low population density causes the safety risks to decrease. Areas in which the safety risks are lower, are more likely to finish regulations about the use of unmanned cargo aircraft. Consequently, the conclusion can be drawn that the public health, which is directly influenced by the population density, has influence on the laws within an area and thus on the legal accessibility of that area.

Besides the population density, other laws (labour-, employment-, and consumer laws) determine the legal accessibility of an area.

So far indicators have been determined for six categories, namely economical, societal, technological, political, environmental and legal. The environmental dimension was included since this dimension was added to the PEST approach in the mid-nineties by Birnleitner (2014). The only dimension for which factors still have to be identified is the geographical dimension. This is done in section [1.3.7].

1.3.7 Geographical area attractiveness

Rodrigue *et al.* (2006b) describe the geography of transportation systems. In this context geography should be interpreted as the physical features of the earth and its atmosphere influencing the human transportation activities in terms of resources, political and economic activities (Oxford dictionaries, 2019; Rodrigue *et al.*, 2006b). The overall goal of any transportation network should be to transfer all attributes of passengers, freight or information from an origin to a destination (Rodrigue *et al.*, 2006b). The extent to which freight flows directly from one location to another is called connectivity (Rodrigue *et al.*, 2006b).

Connectivity

Connectivity describes the extent to which transportation is possible whereas transportability refers to the *ease* with which passengers, freight or information can be transported (Rodrigue *et al.*, 2006b). UCA are designed to serve some of the most remote geographical areas (PUCA, 2013a). Connectivity is used to describe the extent to which freight flows to and from these remote locations. Connectivity has three main types of effect, namely economic -, network - and spatial effects (Rodrigue *et al.*, 2006b).

Connectivity economics

Increasing the connectivity between two locations enables less costly commercial interactions between two areas (Rodrigue *et al.*, 2006b). Koopman (2017) describes the way in which UCA can help unlocking the economic potential of a region. By offering a suitable mode of transport, and thus increasing the connectivity, regions that had no access to any infrastructure before will now be able to transport and receive goods which can help stimulate the local economy. Consequently, connectivity economics is indicated by the factors treated in section [1.3.3].

Connectivity network

The connectivity network describes the physical properties of the network that is needed to transfer freight. Since UCA are designed to reach remote places, connectivity remains high. Network attributes are capacity and flexibility. Prent (2013) argued that the route flexibility and smart network designs can significantly lower the operation cost of UCA. The main actors within transportation networks are the physical facilities needed to process the cargo and the authorities and ministries necessary to give permission for the transportation of freight.

Spatial connectivity

The spatial structure of areas influences the connectivity (Rodrigue *et al.*, 2006b).

UCA will be servicing spatial entities like metropolitan areas, industry parks or remote rainforests. Differences in spatial distribution often result in differences in social equity. Because transportation activities often cluster around the most connected areas, inequalities in development opportunities arise (Rodrigue *et al.*, 2006b).

Geographical accessibility

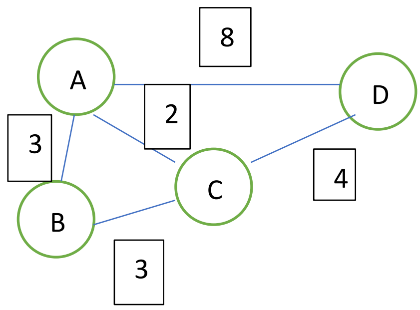
PUCA (2013a) aims at developing a transportation network that enables the transportation of goods from anywhere to everywhere in the world. Fulfilling this vision requires locations being geographically accessible for such networks. Accessibility is defined as the easy with which a location or area can be reached (BusinessDictionary, 2019) The most commonly referenced measure of geographical accessibility is the one from Geurs and Ritsema (2001). They differentiate between accessibility in terms of infrastructure, activity-based measures and utility-based accessibility measures. Stefancic *et al.* (2006) substantiate this theory by defining accessibility as the activities that can be done within a given time and cost. Rodrigue *et al.* (2006b) define the geographical accessibility of an area as the summation of all distances to other locations from that area divided by the number of areas with which there is a connection. Geographical accessibility can be calculated using the following formula (Rodrigue *et al.,* 2006b).

$$A(G) = \sum_{i}^{n} \sum_{j}^{n} d_{ij}/n$$

where d_{ij} is the shortest path from location i to j and n represents the total number of locations. The lower the value, the more accessible the location is. Because there is doubt about the quotation of this formula, an alternative formula has been developed.

$$A_i = \sum_{i}^{n} d_{ij}/n$$

Such that i ≠ j. In this formula A_i is the accessibility of city i, d_{ij} the shortest path from location i to j and n represents the total number of locations. To clarify this formula an example follows below with the following four fictional locations; A, B, C, D. The purpose of the formula is to find the location that is most accessible geographically. The location of the four cities is as such that city D can only be reached from B via C.



These values are then placed into a matrix, of which the last column represents the sum of each row.

	A	B	C	D	Sum
A	-	3	2	8	13
B	3	-	3	7	13
C	2	3	-	4	9
D	8	7	4	-	19

After this matrix has been set up, the only thing left to do is to divide the total distance from each city by the total number of cities. Since the total number of cities if fixed (four in this example), it can be seen that city C is the most accessible.

Up till now, the six categories from stage one of the four stage selection model (Fig. 2) are provided with indicators derived from the literature. Kreutzer (2006) and Hofbauer *et al.* (2009) invented the term macro environment which served as an umbrella term for four of the six categories from Fig. 2, namely economical, societal, technological and political. The PEST approach has been used to assign indicators to these four categories (Pfaff, 2004). After the PEST approach was extended with the legal and environmental category also these categories could be assigned indicators to. This has been done using literature published by the Platform Unmanned Cargo Aircraft. The last category, geography, has been provided indicators using The Geography of Transportation Systems (Rodrigue *et al.,* 2017).

The following page provides a complete overview of the most important results based on the literature revision (Fig. 3). Herein the seven different categories with the associated attributes and factors are indicated with different colours. These colours will be used throughout the report, so that one is able to find out at any time which category the factor belongs to. To increase the readability of the figure, it was decided to make the page lay-out landscape.

PEST Category	Attribute	Subdivision of attribute	Factor (indicator)	Sub-Factor
Economic factors	Customers		Customer presence	High time-value goods presence
	Competitors		Competitor presence	
	Market economics		Area remoteness	Area product prices
	Economic efficieny	Time efficiency	Travel time	Existence of direct connections
		Distance efficieny	Minimal transportation distance	
			Quality of area infrastructure	
		Energy efficiency	Output/input ratio	
		Cost efficiency	Transportation cost	
			Transportation productivity	
			Logistics cost	
			Transport capacity utilization	
Technological factors	Research and Development	UCA accomodation facilities	Facility presence	
Political factors	Regulations		In/export regulations	
			Political stability	
			Tax policies	
			Trade restrictions	
		Safety	Personal injury accidents	Population density
			Population insecurity	
			Number of UCA being hijacked	
Societal factors	Quality of living		Locked economic potential	Presence of belly freight/conventional cargo
Environmental factors	Economic efficiency		"Economic factors"	
	Environmental impact		Public health	
			Air quality	Noise pollution
				All sorts of emissions
	Social Equity	Accessibilty	Isochronic measures	Accessibiltiy within a given travel time or distance
			Gravity-based measures	Accessibility as function of distance
Legal factors	Public health		Population density	
Geographical	Connectivity	Economic connectivity	Locked economic potential	
		Network connectivity	Physical facilities	
			Political factors	
		Spatial connectivity	Social equity	
	Accessibility	Geographical accessibility	Geographical accessibility A(G)	
		Potential accessibility	Potential accessibility A(P)	

Figure 3: Literature review overview

1.4 Causal relationship model

Not all factors can be specified up to the same level of detail. In other words, not all factors in Figure 3 consist of sub factors. To indicate as detailed as possible which factors influence the main variable, it has been decided to use the 'factors' (Column 4 Fig. 3) and if present the 'sub-factors' (Column 5 Fig. 3) in the instrument. From these factors only the factors that have a causal relationship with the main variable 'area attractiveness' will be taken into account. To test whether there exists a causal relationship between a factor and the main variable the book Geen Probleem (2012) will be used. The factors that have a causal relationship with the main variable will be reflected in a causal model (Fig. 5). Geen probleem (2012) mentions three conditions which need to be met in order for a relationship to be causal. [1] Sequentiality exists. The cause always has to occur prior to the consequence. This is tested by asking the question: "Does the factor occur prior to a change in the area attractiveness?". [2] There is a statistical relationship. If the value of one of the indicators changes then also the value of the area attractiveness has to change. For some factors the question about the nature of the relationship between them could not be answered. These factors do not meet the statistical relationship requirement for causality. [3] There are no alternative solutions for this part of the problem. It must be these indicators that cause the area attractiveness to change. For all factors, these three requirements have been checked as can be seen in Figure 4 on the next page. During the causality check a number of factors turned out to be duplicate. Duplicate factors were 'competitor absence', 'facility presence' and 'population density'. These factors are only mentioned once in the causal model. Those factors that meet all three requirements are displayed in the causal relationship model displayed in Figure 5 on page 22. Furthermore, the causal relationships in Figure 5 have been appointed either a plus, minus or 'X' sign. A *plus* sign indicates that an *increase* in the variable at the beginning of the arrow also causes an increase in the variable at the end of the arrow. A *minus* sign indicates that an increase in the value of the variable at the beginning of the arrow leads to a *decrease* in the value of the variable at the end of the arrow. An 'X' sign means that there is probably a relationship between two variables, but the exact nature of this relationship is unknown. For example, if the quality of the infrastructure within an area becomes increasingly worse (↓), the attractiveness of that area for UCA deployment increases (↑) and thus the relationship will be assigned a minus sign. Both the minus- and plus sign are displayed in Figure 4.

Var 1 ↑ → Var 2 ↓ = -

Var 1 ↑ → Var 2 ↑ = +,

Figure 4: Coding scheme causal relationships

Apart from the causal relationship that the factors may have with the main variable, it is also possible for the factors to serve as so called conjunction criterion. These are requirements that have to be met in order for the area to be taken into account. It was preceded not to include the conjunction criteria into the causal model in order to keep it as clear as possible. It is also possible that the indicators are correlated or (partly) overlap. To be 100 percent sure whether a set of indicators is correlated or not, statistical tests are needed. To keep the applicability of the model as broad as possible, overlapping factors will not be removed. However, the correctness of the list of factors will be discussed in section [3.3.1] A follow-up study will have to be conducted to determine the correlations between the factors and thus to increase the validity of the instrument.

Factor (Literature)	Main Variable	Sequentiallity	Statistical relationship	No alternative solutions	Causal relationship	Conjunction criterion
High time-value goods presence	Area attractiveness	Yes	Yes	Yes	Yes	
Competitor absence	Area attractiveness	Yes	Yes	Yes	Yes	
Area product prices	Area attractiveness	Yes	Yes	Yes	Yes	
Existence of direct connections	Area attractiveness	Yes	Yes	Yes	Yes	
Minimal transportation distance	Area attractiveness					X
Quality of aera infrastructure	Area attractiveness	Yes	Yes	Yes	Yes	
Output/input ratio	Area attractiveness	No	Yes	Yes	No	
Transportation cost	Area attractiveness	Yes	Yes	Yes	Yes	
Transportation productivity	Area attractiveness	No	No	Yes	No	
Logistics cost	Area attractiveness	Yes	Yes	Yes	Yes	
Transport capacity utilization	Area attractiveness	No	No	No	No	
Facility presence	Area attractiveness	Yes	Yes	Yes	Yes	
	Area attractiveness					
In/export regulations	Area attractiveness					X
Political stability	Area attractiveness	Yes	Yes	Yes	Yes	
Tax policies	Area attractiveness					X
Trade restrictions	Area attractiveness					X
Population density	Area attractiveness	Yes	Yes	Yes	Yes	
Population insecurity	Area attractiveness	Yes	Yes	Yes	Yes	
Number of UCA being hijacked	Area attractiveness	No	No	No	No	
	Area attractiveness					
Presence of belly/conventional cargo	Area attractiveness	Yes	Yes	Yes	Yes	
	Area attractiveness					
"Economic factors"	Area attractiveness					
Public health	Area attractiveness	No	No	No	No	
Noise pollution	Area attractiveness	Yes	Yes	Yes	Yes	
	Area attractiveness					
	Area attractiveness					
Accessibility within a given travel time or distance	Area attractiveness					X
Accessibility as function of distance	Area attractiveness					X
	Area attractiveness					
Population density	Area attractiveness	Yes	Yes	Yes	Yes	
	Area attractiveness					
Locked economic potential	Area attractiveness	Yes	Yes	Yes	Yes	
	Area attractiveness					
Physical facilities	Area attractiveness	Yes	Yes	Yes	Yes	
Political factors	Area attractiveness					X
Social equity	Area attractiveness	No	No	No	No	
	Area attractiveness					
A(G)	Area attractiveness	Yes	Yes	Yes	Yes	
A(P)	Area attractiveness	Yes	No	No	No	
Factor (Expert knowledge)						
Return freight	Area attractiveness	Yes	Yes	Yes	Yes	
Delivery reliability	Area attractiveness	No	No	No	No	
Product value vs added value	Area attractiveness	Yes	Yes	Yes	Yes	
Space to accommodate UCA	Area attractiveness	Yes	Yes	Yes	Yes	
Life lap	Area attractiveness					X
Green image	Area attractiveness	No	No	No	No	
Transportation urgency	Area attractiveness	Yes	Yes	Yes	Yes	
TOTAL					**21**	**8**

Figure 5: Factor causality check

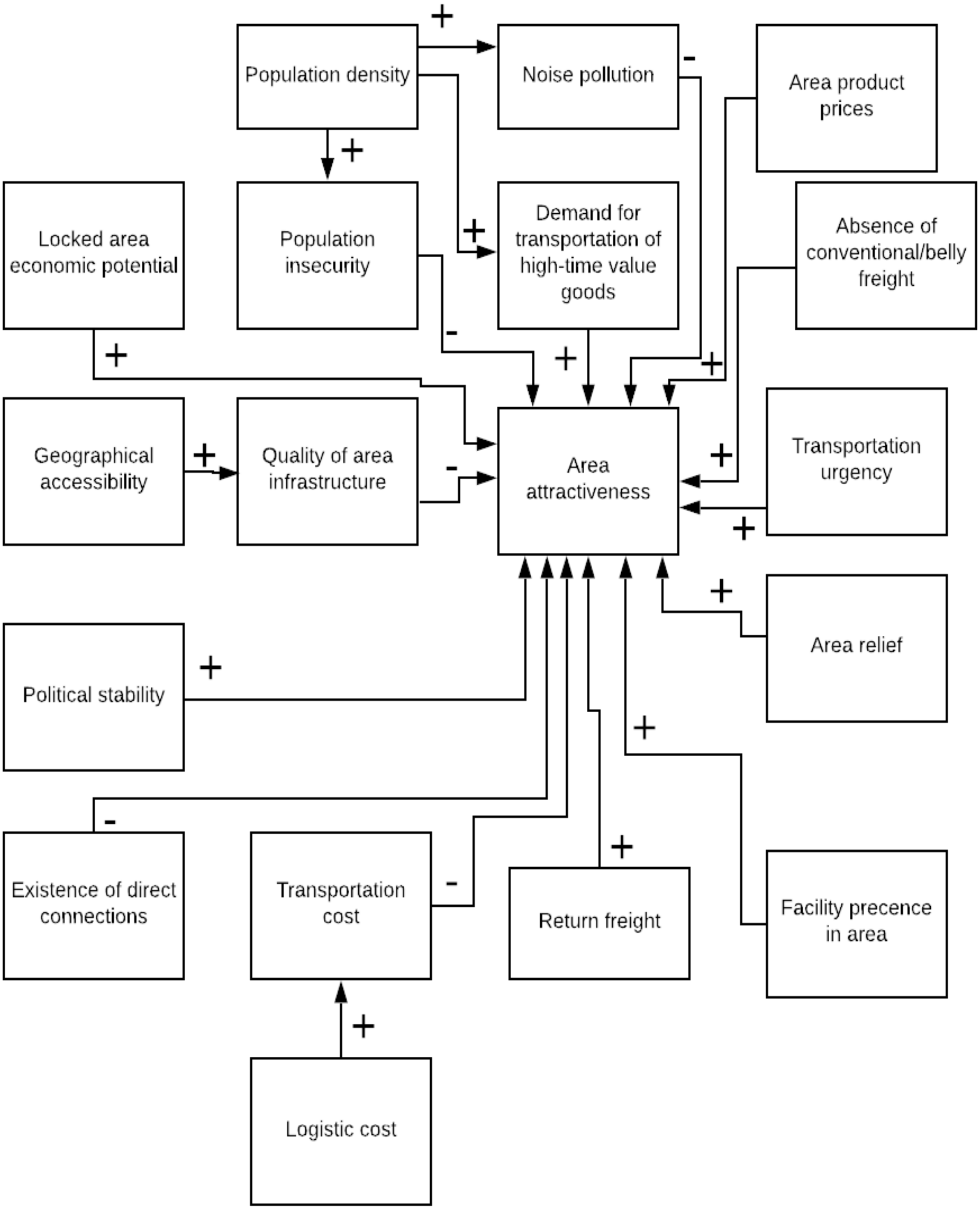


Figure 6: Causal relationship model

1.5 UCA Characteristics

This second part of the literature review consists of describing the most important characteristics of large unmanned cargo aircraft. Former Bachelor and Master theses performed on behalf of PUCA will be consulted to get an overview of these characteristics. The following research question will be covered in this part.

[2] *What are the most important characteristics of unmanned cargo aircraft?*

1.5.1 Physical UCA properties

In this report, the term unmanned cargo aircraft (UCA) refers to unmanned aerial vehicles capable of transporting up to 20 tonnes at a maximum range of 10 000 km (PUCA, 2013a). Besides a weight-based classification of drones, drones can be classified according to their technology (de Lange *et al.*, 2017). Since no humans need to be accommodated shapes like the Blended Wing Body (BWB) or flying wing can be used saving up to 15-20% on aerodynamic efficiency compared to conventional cargo aircraft (PUCA, 2013a). It is expected that the first long-range UCA versions will not Vertically Take-Off and Land (VTOL). Heerkens (2018) substantiates this statement by claiming that too much thrust will be lost for UCA to be able to deliver enough upward force. It is also Heerkens (2011) who argues that unmanned means lower cost while achieving higher productivity. The lower cost is realized through the fact that no pilots (or on-board crew) has to be present. PUCA (2013a) substantiates Heerkens' argument about higher productivity. PUCA (2013a) describes several UCA-specific benefits which can either enlarge UCA productivity and/or lower UCA cost. The same benefits are described by De Lange *et al.* (2017). The propose the following benefits when using UCA: [1] Unmanned aircraft do not need pressurized cabins, resulting in lower fuel cost due to improvement of the aerodynamics. [2] Absence of humans make flight duration no longer an issue, speeds can be optimized to make fuel consumption even more efficient. [3] Intended BVLOS control makes it possible to control multiple aircraft with one operator, thereby reducing the labour costs. [4] Flexible take-off and landing locations allow UCA to land almost anywhere in the world. Many of the above-mentioned benefits apply to the use of relatively small UCA with a payload up to 20 tonnes (PUCA, 2013a). Van Groningen (2017) describes the benefits and limitations of the use of unmanned cargo aircraft that apply to this study. An overview of these benefits and limitations can be found in Table 1.

UCA Benefits	*Savings in terms of*	*Increased flexibility*	*Transport time*	*Use Limitations*
No crew in flight	Labour cost	No 'fixed home base'	No duty length restriction	Legalisation Safety issues
Optimized airframe	Fuel cost	Longer range compared to manned aircraft	Increased transported time due to low cruise speed	Airframe limitations unknown
Route flexibility	Less idle time	Able to land on short runways or roads	Direct routes possible resulting in lower transport time	No limitations known
Sustainability	Less air pollution Fuel cost	No impact	Increased transported time due to low cruise speed	No limitations known
Optimized cargo handling	Less Damage Less Handling time	Ease handling so less facilities needed	Less idle time due to handling so shorter total transport time	No limitations know
Little required infrastructure	Less transfers of goods required	Able to land almost anywhere	Less transfers so shorter total transport time	Legalisation (permission to land)

Table 1: UCA benefits and limitations (Source: Van Groningen, 2017)

All of the aforementioned benefits are a result of the design of unmanned cargo aircraft. But, as correctly stated by PUCA (2013a), some benefits can be realized by deploying UCA in certain ways. Often these benefits are realized through deploying UCA in certain areas or for specific purposes. Grootens (2016) conducted a case study in which he examined the delivering of medicines in Congo's rainforest. In this case study, UCA are beneficial compared to other modes of transport by being able to fly over the rainforest. As an example, UCA transportation in this specific situation is over 100 times faster than transportation by truck[2]. Another case study is conducted by van Groningen (2017). Van Groningen (2017) researched the cost benefit of transporting goods with UCA between Asia

[2] Transportation by truck requires 468 hours whereas UCA could do the same transportation in only 4,23 hours (Grootens, 2016).

and Europe. Van Groningen (2017) concluded that UCA, due to their design, are ideally suited to transport high-time value goods in flexible networks. From these two case studies show that the benefits of using UCA differ per situation. Thus, besides area independent design benefits, unmanned cargo aircraft also have benefits which are area dependent. In order to map the relationship between UCA and the area in which they are being deployed, a business model canvas will be used.

1.5.2 UCA Business Model Canvas

The aim of this research is to develop an instrument that can help potential UCA users decide where to deploy their aircraft. For this reason, the business model canvas does not describe UCA itself but instead their relationship with the areas they are deployed in. The first stage in developing the business model canvas is translating the vision of the platform unmanned cargo aircraft into a discrete value proposition. This value proposition is described in Table 2. To be able to carry out this value proposition, two important customer segments must be present. The first type of customer are companies who would like to use UCA to transport their goods with shippers (Koopman, 2017). Revenue generated by these customers is likely to be on a pay-per-use basis. A well-known example of this is provided by Zalando, a German web shop that distributes its goods using local delivery companies (Wikipedia, 2018). The biggest benefit for users in this case is the fact that no large investments in the purchase of UCA are required. The second segment is formed by customers who are willing to buy UCA.

The goal of large UCA is to deliver up to 20 tonnes of high-time value goods anywhere on the planet with a maximum range of 10,000 km (Koopman, 2017). PUCA (2013a) claims that this value will be delivered through two main applications: [1] Civil UCA will operate in markets that solely support small amounts of freight on so called thin routes. [2] UCA create new markets for small amounts of freight by opening up new routes[3]. Enabling UCA to deliver the proposed value requires a number of key resources. These key resources include; freight demand, UCA, regulations, facilities and communication channels. These activities came to the light during multiple sessions with the chairman of PUCA. Before UCA can start transporting goods, supporting activities need to be performed like setting up regulations, developing a transportation network and developing the actual unmanned cargo aircraft. Realizing these key activities will be done with the help of the partners described in table 2.

UCA will realize revenues in different ways. Koopman (2017) describes the way in which UCA can help unlocking the economic potential of a region. By offering a suitable mode of transport, regions that had no access to any infrastructure before will now be able to transport and receive goods which can help stimulate the local

[3] Koopman (20117) describes five situations in which the opening of new routes is possible. These can be found on https://essay.utwente.nl/73143/1/Koopman_BA_BMS.pdf

economy. A second way of UCA generating revenues is by transporting goods. Customers who want their goods to be transported can use UCA to do so by paying for this. A possible third way of generating revenue is by selling UCA. In this case revenue is earned in the same way a car dealer earns money by selling cars.

Generating revenue cannot be realised without incurring cost. To generate revenue with UCA the operating cost have to be less than the earnings generated by using the aircraft. Additional to these operating costs, maintenance cost is required to keep the aircraft in good condition. Before UCA can start generating revenue in the first place, they have to be developed and built which will be accompanied by very high cost. An overview of the business model canvas can be found in Table 2 on page 27.

<table>
<tr>
<td rowspan="2">Key Partners
Aircraft manufacturers
Shippers
Logistics companies
Governments</td>
<td>Key Activities
Delivering goods from anywhere to everywhere
Developing UCA regulations
UCA development
Network expansion</td>
<td rowspan="2">Value proposition
Delivering up to 20 tonnes of high-time value freight fast and at low cost to anywhere in the world at a maximum distance of 10,000 km</td>
<td>Customer Relationships
An operator rents a UCA out to a shipper who leaves it at its destination where it is rented out to the next client</td>
<td>Customer Segments
UCA can be rented our bought by anyone who needs to transport goods
Military</td>
</tr>
<tr>
<td>Key Resources
Goods in need of transportation
UCA
Regulations
Communication channels</td>
<td>Channels
Conferences</td>
<td></td>
</tr>
<tr>
<td colspan="2">Cost Structure
UCA operating cost
UCA development cost
Maintenance cost
Facilities</td>
<td colspan="3">Revenue Streams
Transportation of high-time value goods
Transportation of perishables
Unlocking economic potential of an area</td>
</tr>
</table>

Table 2: Business Model Canvas UCA (Source: Koopman, 2017; Grootens, 2016)

3

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2. Methodology

So far it has been indicated what factors, according to the literature, influence the area attractiveness regarding the deployment of unmanned cargo aircraft. For this report, descriptive as well as qualitative research has been conducted to be able to answer the question about how we can indicate the attractiveness of an area regarding the deployment of unmanned cargo aircraft. To be able to answer this question two data gathering methods have been used in this research. Literature research has been conducted to collect factors that have the potential to influence the area attractiveness. Interviews were conducted to supplement and verify this list.

2.1 Data collection

In the theoretical framework reports of van Groningen (2017), Lugtig and Prent (2012), Koopman (2017), and Kremers (2012) have been consulted. Besides these reports, articles about 'assessing area attractiveness' have been searched for on Google Scholar, Springer and Scopus. The Dutch 'Kennisinstituut voor Mobiliteitsbeleid' recently published a report in which they discuss the application of unmanned cargo aircraft in their role as airfreight transporters. Besides their application, the kennisinstituut also discusses their market potential and the areas where they are most likely to be deployed in (KiM, 2017). In addition, the recently published report of Grootens researches in what areas UCA can be successfully deployed. Grootens (2016) uses the UCA properties shown in earlier studies to filter different world regions. From the remaining areas he chose the one that is most suitable for carrying out the objective he has developed. To substantiate his choice Grootens (2016) developed criteria for choosing a country. Although some criteria are specifically aimed at the case study, demographic distribution for example, other criteria are more generally applicable, development of infrastructure is an example of this. The study of Grootens (2016) can be viewed upon as a case study that is tried to be generalized in this study.

2.1.1 Interview

The interview has been developed based on this theoretical framework. The interview consists of three questions. All of the questions are open and provide the researcher with qualitative data.

The interviews were open such that the respondents were able to freely describe their findings on the topic of this research. An outline of the interview can be found in Appendices B till D. The goal of the first question was to get a broad overview of what the respondents' value as important when assessing the attractiveness of an area. In the second question the respondents were asked to give their opinion on how to correctly present these indicators. Finally, the respondents were asked about how they would assess the importance of an indicators. The final questions as asked to the respondents are shown in Appendix A.

2.2 Inclusion- and exclusion criteria

Inclusion- and exclusion criteria already have been developed as part of the research proposal. The criteria have been developed as the second step of performing a systematic literature review. In this research, the methodology consists of inclusion and exclusion criteria to select whether an article or report can be used in the revision or not. The inclusion and exclusion criteria used, are summarized below.

Inclusion criteria

- Publication was a study that examined what factors influence transportation problems
- Publication was a study that examined which factors could enlarge the attractiveness of different types of transport
- Academic reviewed study published on the website of the Platform Unmanned Cargo Aircraft.
- Publication was a study that examined the categories on which different modes of transport are being reviewed
- Publication focusses on the deployment areas of transportation modes

Exclusion criteria

- Publication only focusses on one mode of transport
- Publication does not examine the categories on which different modes of transport are being reviewed
- Studies were published in other languages then Dutch or English
- Study focusses on the development of UCA

2.3 Research process

The intention was to conduct an interview with two different members of the platform. These interviews were conducted at the company between 20 to 28 February 2019. The time set per interview was between 20 to 30 minutes. Since the questions were open, qualitative data was gathered during the interviews. During the interviews, notes were made to register the answers.

Because the results of the two interviews deviated very much from each other, additional interviews have to be conducted to be able to determine the reliability of the results gathered.

2.4 Data-analysis

Since no quantitative data was gathered, the data had to be processed by hand. The first step was to transcribe the interviews. This has been done using transcribe software called AmberScript. Since the interview is about the information provided by the respondent verbal transcribing is sufficient here. After transcribing the interviews, the second step is to code the interviews. Coding the interviews has been done using coding software called ATLAS.ti. Because the interviews provide qualitative information, the third step was to group the codes assigned in step two. The code groups indicate similarities in the provided answers. The last step is to draw conclusions upon the information given in the interview. In this case, amendments based on the interview result in a different list of area attractiveness indicators.

2.5 Instrument development

After the data has been collected according to the process described in section [2.1], the data needs to be translated into a form in which the data is suitable to be used in an instrument. To be able to do this, similar researches were looked at. The GIS-based Landscape Appreciation Model (GLAM) emerged from this. GLAM used positive and negative indicators to assign a score to a specific area. Because the model could not be applied in its original form, the GLAM has been adjusted as described in section [4.3]. Thus, a modified version of the GLAM will be used to assig scores to different areas. Since it is assumed that not every user will value the same factors with exactly the same importance, there need to be found a method that takes into account the relative factor importance. The best suitable method in this case is the Analytical Hierarchy Process (AHP) (Saaty, 1987). Here the AHP will be used to discretely compare a pair of factors which reflects the relative strength of preferences. The relative factor strength will then be combined with the area scores to be able to calculate a total relative score per area.

2.6 Validity and reliability

For the purpose of validity, the survey serves as a verification for the information provided by the literature. The interview questions have been selected based on the literature. Only literature relevant for this research question has been used. In addition to this, all of the literature used has been published recently. Besides the right input the method also needs to be designed in such way that it actually indicates the attractiveness of an area. To satisfy this requirement, designing the method will be done based on a report written by (Lankhorst, de Vries & Buijs, 2011). In their study Lankhorst *et al.* (2011) propose a model with which the landscape attractiveness can be mapped based on multiple indicators.

To be able to guarantee the reliability of the instrument developed in this research, the development process is transparent and clearly explained later in this report. The input as well as the sources used to form this input are described.

Chapter two described the type of research that has been conducted, namely descriptive, qualitative research. Chapter two also describes how the data was collected, namely by revising existing literature and by conducting semi-structured interviews. Analysing the data was done with the help of transcription software and coding software, Amberscript and ATLAS.ti respectively. The knowledge from the expert-interviews was used to validate the information found in the literature revision whereas the validity of the instrument was guaranteed by

increasing the variety of factors included in
the instrument.

3. Indicator verification

Chapter one provided an overview of indicators influencing the attractiveness of a location according to the literature. In the second section of chapter one, reports written by van Groningen (2017); Prent (2013); Koopman (2017) and Grootens (2016) were conducted to establish the most important characteristics of Unmanned Cargo Aircraft. This chapter discusses the most important findings that came forward during the expert interviews.

To my best knowledge there is no literature available about how to assess the relevance of the beforementioned factors regarding unmanned cargo aircraft deployment. The relevance of these factors is verified by conducting multiple interviews with possible UCA users. In this way, an attempt is made to find out whether the list of factors in chapter one already is complete or should be supplemented. Not all potential UCA users are suitable to conduct an interview with. The following inclusion criteria were developed to select suitable respondents.

Inclusion criteria

- Respondent must have interest (personal/professional) of any type (economical, strategical, etc.) in the deployment of unmanned cargo aircraft.
- The respondent must be available to contact via phone or email.
- The respondent must be willing to cooperate.

Two possible respondents remain after application of the inclusion criteria. Due to privacy concerns, the identity of the interviewees will remain anonymous. The interview with respondent Y was not recorded due to privacy concerns. For the same reason, no transcribed version of this interview is included in the Appendix.

Respondent X did research about developing a UCA system. Respondent X also functioned as supervisor of a student who did research in the same field. Respondent Y. Respondent Y is Project and Product Manager at Rhenus Logistics. Respondent Y is researching the possibilities of using UCA within a large logistics firm.

3.1 Interview Respondent X

Appendix A represents the questions asked to the respondents. Appendix B represents the transcription of the interview with respondent X. Coding the transcribed interview with Respondent X revealed a number of factors that not have been discussed in the literature. This concerns the following factors.

- Return freight

According to Respondent X, return freight is important in selecting an UCA deployment area because return freight can halve the price of a flight. Return freight is simply the freight that can be taken on the way back. Because UCA do not fly back empty, in this way the transportation efficiency and profitability are improved. In addition, the reduction of empty flights reduces CO_2 emissions.

- Delivery reliability

Delivery reliability is the extent to which UCA are capable of delivering on time and in full. Delivery reliability is key when transporting with UCA. UCA are likely to operate within so called Just-In-Time supply chains. For example, the delivery reliability must be very high when UCA transport spare parts needed to keep an oil rig from getting stuck.

- Product value vs added value

According to Respondent X, the products transported using UCA must add much value in order to overcome the high UCA transportation cost. This value can be added in one of the following two ways. [1] The product has high value and/or [2] the product is time essential. In the first case the higher transportation costs are offset by the value of the product. In the second case, the product must be transported in a time-bound manner which entails higher transportation cost.

3.2 Interview Respondent Y

In the interview with Respondent Y, the emphasis was on a completely different application of UCA. Within Rhenus Logistics, the UCA business case is about last-mile delivery in alarming situations. In alarming situations, like natural disasters for example only a few options, to reach those in need of help, exist. The helicopter for example is one of the most expensive modes of transport to reach the locations where help is needed. In addition, to facilitate a helicopter at least one or two football fields are needed. In the vast majority of situations that occur, this space will not be present at the site of the disaster. From this UCA application the following factor, which is not described in the literature, can be derived.

- Space to accommodate UCA

Simply put, space to accommodate UCA is the space UCA need to safely land and take-off. To decrease the space needed to accommodate UCA, Rhenus Logistics demands an unmanned cargo aircraft capable of dropping a few boxes without having to land. This implies that the prices, when it all goes well, are way below the prices of the current solutions. According to Respondent Y this UCA application is the most viable due to large laws and regulations limitations. Laws and regulations have already been addressed in Chapter two. However, in the theoretical revision the importance of legislation and regulations is underexposed. Laws and regulations concerning drones with a payload of only 250 grams required years and years of debating. To avoid the bottleneck of laws and regulations, the use of UCA should be focussed on the life lap.

- Life lap

In the context of this research, life lap means that limitations proposed by legislation and regulations are subordinate to the benefits that can be achieved through the use of UCA. After it has been successfully proven that UCA can safely transport relief supplies in affected areas, then UCA can potentially be deployed to transport other types of goods.

According to Respondent Y transportation cost depend on two factors. [1] The instrument that is used and [2] the people involved with that. As substantiated by PUCA (2013a), optimising both components result in lower transportation cost. Additionally, respondent Y mentions that companies who use UCA will have a more sustainable image towards the public.

- Green image

Green image is the extent to which companies and organisations appear to act responsible. In addition to saving on transport cost in the long term, an indirect cost saving of using UCA is that one third up to two third of the trucks can be taken out of service. This is a cost saver because it decreases the congestion cost. However, this effect can only be accomplished by setting up corridors in which UCA can fly continuously.

- Transportation urgency

Transportation urgency is the necessity with which a product must be transported. Urgency was mentioned the most important economic factor that makes an area attractive. Respondent Y mentions the example of an oil rig that is likely to get stuck if certain parts are not soon available. In this example, the higher transportation cost for transporting through the air, are justified by the urgency with which to transport.

Finally, follows the most important conclusion that can be drawn from the interview with Respondent Y. Prent (2013), after conducting research about the market for unmanned cargo aircraft, concluded that UCA operate in markets where there is no direct conventional or belly freight possible. In contrast to this, is the argument of Respondent Y who states that the cargo follows the passage. Respondent Y added “you do not send cargo to areas where there are no people” (2019). According to Respondent Y, the bellies of passenger planes are full. In addition, not every type of freight is suitable for transporting as belly freight. This unsuitability can be caused by [1] the dimensions of the goods, [2] the weight of the goods and [3] lastly due to the nature of the goods. According to Respondent Y, at least 50 percent of all the freight transported is subject to one of the above-mentioned causes.

By conducting two expert interviews, several factors have emerged that are not described in the literature yet. Since these factors are identified by people who actually have interest in, or work with UCA, it is assumed that these factors are relevant enough to be included in the model.

Thus, the following factors are added to the list in Figure 3.

- Return freight
- Delivery reliability
- Product value vs added value
- Space to accommodate UCA
- Life lap
- Green image
- Transportation urgency

3.3 List quality

All the factors that should be included in the instrument are now identified. Before these factors are put into an instrument, it is necessary to make a number of statements about the quality of the list of factors. The quality of the list is determined on the basis of the correctness, completeness and consistency (Zowghi & Gervasi, 2002).

The concepts presented above can be proved in either of the following two ways. The first way is to formally proof the three C’s. Usually this is done in situations where the safety is critical. This is not the case in this research and thus will be chosen to prove the three C’s in the second manner; informal proof. The informal proof for the three C’s follows next.

3.3.1 Factor list correctness

Correctness of the list of factors can be interpreted in two ways. The factors should provide the right information in the first place. Secondly, the factors should be documented accurately. Verification is the process of checking whether these factors actually contribute to solving the research question. The main variable within the research question is the area attractiveness. Verification of the indicators has been done using the book Geen Probleem (2012). Only those factors that have a causal relationship with the main variable have been included in the instrument. On the other hand, validation is the process of assessing the factor completeness. In other words, validation can be done by answering the following question. *Have all the factors needed to assess the attractiveness of an area been mentioned?* In order to be able to answer this question in the affirmative, the variety of factors included in the instrument has been kept as large as possible. So, the correctness of the factors can only be established by asking about the relationship between the factor and the goal.

3.3.2 Factor list completeness

Factors indicating the attractiveness of an area regarding the deployment of UCA in that area will never be totally complete. Since research about unmanned cargo aircraft and their deployment location still evolves, it is reasonable to think that the requirements which the area is scored on also evolve. Shortly stated, due to the constantly changing needs of customers and users, the list of factors will never be totally complete.

3.3.3 Factor list consistency

In the context of this research factor consistency means the factors having no overlap, no contradictions and no duplications. Besides this, the factors need to be logically consistent. In the following section the inconsistencies will be removed from the list displayed in Figure 3.

Many of the factors displayed in Figure 3 are interrelated. When a causal relationship between two variables is expected, correlation tests should be performed to evaluate the association between two or more variables. Correlation tests are treated in more detail in section 7.2. Interrelation between two or more variables does not automatically lead to overlap between the variables or the variables being duplicates of one other. First, the factors are checked on whether or not they conflict with other factors.

Duplicate factors

The first two variables that seem to overlap partly with each other are competitor presence and Presence of belly/conventional cargo. Because belly/conventional freight are seen as competitors of UCA transportation, the above two factors are therefore substantively the same. Therefore, only Presence of belly/conventional cargo has been included in the causal model in Figure 5. The second duplicate pair of factors is population density. Population density is used as an indicator for both the political and legal category. However, the keep the list of factors consistent, population density is only mentioned once in the causal relationship model. The third duplicate pair of factors is formed by trade restrictions and in/export-regulations.

Both factors describe the regulations imposed by the government on the transport of goods. For this reason, only trade restrictions will be included in the instrument. The fourth pair of duplicate factors is formed by political factors and tax policies. Tax policies are part of political factors and will therefore not be treated as an individual factor. Transportation cost and logistics cost will not be treated separately. Transportation cost are part of organisations' logistics cost. Only the costs associated with transporting goods with UCA are interesting for this study. Therefore, logistics cost will not be included in the instrument.

Conflicting factors

The list of factors in Figure 4 contains a number of factors that directly affect each other. A good example of this is formed by Population density and Noise pollution. The greater the population density in an area, the more people can and will be affected by noise. However, there are no factors in the list that exclude other factors.

4. Instrument development

Chapters one and three elaborated on the input for the instrument. The design and development of the instrument is described in this chapter. The complete list of variables and a rule on how to actually decide which area is the most attractive, will be combined into one instrument. This instrument is based on the Analytical Hierarchy process (Saaty, 1987). The AHP is an effective tool in dealing with complex decisions and consists of three consecutive steps.

4.1 Analytical hierarchy process

It is likely that everyone has a different idea about how important a particular factor is. This assumption causes the need for a decision rule. The decision that has to be made consists of choosing between multiple locations/areas in this case. The locations all score different on the different criteria set up in chapter one and three. Objective data is available on how each location scores on each criterion. Subjectivity comes into play when a decision maker has to indicate which criterion, he or she considers important. Literature proposes the AHP method (Saaty, 1987). The AHP is a consistent way to let decision makers find a suitable decision among a set of options and a set of criteria (Saaty, 1987). The AHP consists of three consecutive steps.

1. Computing the vector of criteria weight.
2. Computing the matrix of option scores.
3. Ranking the options.

The goal of the decision in this research is to *be able to decide on where to deploy unmanned cargo aircraft operations.* All geographical locations on the planet can be theoretical suitable for UCA deployment. In this research a distinction is made between regions, areas and locations. The world is divided into eight regions according to the U.S. Department of Homeland Security (Cook, 2018). The regions eight are: [1] Africa, [2] Asia, [3] Caribbean, [4] Central America, [5] Europe, [6] North America, [7] Oceania, and [8] South America. Within these regions there are numerous areas. For example, the Amazon rainforest is a well-known area that covers an area of six million square kilometres (The Editors of Encyclopaedia Britannica, 2014). Within these areas there are locations that can be indicated exactly using geographical coordinates.

4.1.1 Pairwise comparison matrix

AHP step one consists of computing the vector of criteria weight. Computing weights for different criteria requires the creation of a *pairwise comparison matrix* **A.** Matrix **A** is a $m*m$ real matrix in which m represents the number of criteria. In matrix **A**, the a_{jk} entry represents the importance of criterion j relative to criterion k. If the value of a_{jk} is bigger than 1, then criterion j is more important than criterion k. If the value of a_{jk} is smaller than 1, then the other way around holds true. Ishizaka (2012) proposes the following constraint.

$$a_{jk} * a_{kj} = 1$$

This constraint ensures that the user only has to fill in the upper half of the pair wise comparison matrix since the lower half can simply be calculated by dividing one by the number entered (reciprocal value).

According to Saaty (1987), the relative importance between two criteria is indicated using a numerical scale from 1 to 9 as indicated in table 3.

Value of a_{jk}	Interpretation
1	*j* and *k* *equally important*
3	*j* slightly more important than *k*
5	*j* more important than *k*
7	*j* strongly more important than *k*
9	*j* is absolutely more important than *k*
2,4,6,8	Intermediate values between two adjacent judgements

Table 3: Scale of relative importance (Saaty, 1987)

After matrix **A** has been completed (displayed in Appendix C), the next step is to normalize the matrix. Normalization of matrix **A** is done because this enables a first interpretation of the relative weights added to each criterion. Matrix **A** can be normalized by dividing each entry by the column total. The normalized matrix **A** can be found in Appendix D. The contribution of each criterion to the goal set at the beginning of the AHP is determined by calculations made using the eigenvector. The eigenvector describes how the total importance is divided among the 21 factors. The more important a factor is, the bigger the value of its eigen vector. The normalized matrix **A** together with the eigenvalue calculations can be found in Appendix D and E respectively.

Ranking three factors from most important to least important is not that hard. However, ranking 21 factors from most important to least important is almost impossible. Thus, in this study the AHP is used as a tool to assign relative weight to a factor. The AHP is also used to rank alternatives. However, in this research the alternatives and their scores on certain criteria are not subjective. Alternatives are assigned a fixed score per criterion. Subjectivity comes into play when decision makers have to assign relative importance to each criterion.

In addition to the AHP, an adjusted version of the GIS-based Landscape Appreciation Model (GLAM) will be used to score every alternative (location or area) on every criterion. The total score per alternative is calculated using the following formula.

$$S_i = \left(\sum Positive\ indicators - \sum Negative\ indicators\right) * selection\ indcators$$

4.2 Adapted GLAM-model

Lankhorst *el al.* (2011) derived attributes from a large body of knowledge[4]. Lankhorst *et al.* (2011) used these attributes as input for the GIS-based Landscape Appreciation Model (GLAM). This GLAM-model uses national available data about the physical aspects of a 250 x 250 metre cell to predict the attractiveness of that area. Since the

[4] A large array of attributes has been evaluated since the 1980's (Ulrich, 1983; Zube, 1987; Kaplan and Kaplan, 1989; Purcell and Lamb, 1998; Strumse, 1994; Aoki, 1999).

decision set *X* consists of eight possible deployment areas, the GLAM model will be adjusted such that it uses available data for the eight areas to determine their attractiveness on the 21 different criterions. The original GLAM model distinguishes between positive and negative indicators (Lankhorst *et al.*, 2011). The choice of the indicators in this research is the result of the mentioned literature and the interviews conducted among members of the Platform Unmanned Cargo Aircraft. The distinction positive- versus negative indicators follows next. Indicators categorized under positive are indictors of which the values need to be as high as possible, negative indicators are factors of which the value must be as low as possible. In the adjusted version of the GLAM model, an additional category of indicators is added, namely selection indicators. Selection indicators are requirements that must be met. Their value nor their relative weight is not important; the requirement can either be met or not. The categorization of the 22 factors can be found in Figure 6.

GLAM model indicator classification	Positive	Negative	Selection
High time-value goods presence	P		
Competitor presence		N	
Area product prices	P		
Existence of direct connections		N	
Quality of area infrastructure		N	
Transportation cost		N	
Facility presence	P		
Population insecurity		N	
Noise pollution		N	
Population density		N	
Locked economic potential	P		
Geographical accessibility A(G)	P		
Return freight			S
Transportation urgency	P		
Minimal transportation distance			S
Trade restrictions			S
Accessibility within a given travel time or distance			S
Accessibility as function of distance			S
Political factors			S
Life lap			S
Space to accommodate UCA			S
Delivery reliability	P		
Total (Sum)	7	7	8

Figure 7: Indicator classification

4.2.1 Preference level per indicator

The description of the indicators in Figure 4 can be found in the theoretical framework. Based on these descriptions, all-encompassing different elements, defining indicator levels is not easy. A method must be found which enables the comparison of two different indicators. Based on the research of Lankhorst *el al.* (2011) every indicator can be valued at one of the following five levels: 0 indicator is not present, …., 4 strong factor presence. Scoring 0 to 4 for positive indicators means that the indicators become increasingly preferred, from least preferred to most preferred, whereas for negative indicators this holds true the other way around. The measure level of the positive and negative indicators can be interpreted as an interval. A factor can have the value '0' but this does not mean that the factor is absent. It may be that when operationalizing the variables, it appears that a correct definition cannot be given for every value from 0 to 4. In this case the scoring interval will either be reduced or not fully used. This is usually the case for variables for which no existing classification is known. Selection criterion can only have two values; 0 the selection criterion is not met or 1 the criterion has been met. The computation method per indicator is described below, starting with the positive factors followed by the selection indicators and closed with the negative factors.

4.3 Operationalising the factors

This section describes the operationalization of the positive, negative and selection indicators. In this context operationalising means that the factors are made measurable. The value of some factors can be looked up in online accessible databases while the value of other variables needs to be calculated or have to be traced by logical reasoning. The values of the factors will have to be converted into scores on the basis of the index table for each factor.

4.3.1. Operationalising the positive indicators

First the positive factors identified in chapters one and three and displayed in Figure 6, are operationalized.

Operationalising both the positive and negative indicators is done using criteria that is developed with common sense. For example, it is logical that the factor 'return freight' is expressed in a quantity of tonnes of return freight. Where the original GLAM uses geographic information systems (GIS) to get the required information, this research uses all kinds of open sources. Because more than just spatial data is needed to assign scores to the different areas, public available information will be used. For a given moment in time, the score of an area per factor is fixed. However, it is not likely to assume that every area has the same score on each criterion at a later point in time. For this reason, the data sources will be described explicitly to make the process of scoring the areas per factor, repeatable.

High time-value goods presence

The presence of high-time value goods in an area turned out to be important because these goods can offset the higher transportation cost (Prent, 2013). To my best knowledge, no classification is available that scores areas on the presence of such goods. Therefore, a classification has been made up based on what has become known during the execution of this research. High valuable parts suitable for transportation with UCA are machinery or replacement parts. Time sensitive goods suitable for transportation with UCA consist of any goods that need to be transported fast in order to prevent a production facility from coming to a standstill. The score classification follows below.

High time-value goods presence	Score
Goods of high value and time sensitive	4
-----	3
Goods either of high value or time sensitive	2
-----	1
Goods have no value and are not time sensitive	0

Table 4: Time-value goods index

Geographical Accessibility

Rodrigue et al. (2006b) describe a formula with which the geographical accessibility of a new transportation system can be calculated. (toeliching bij zetten)

$$A(G) = \sum_i^n \sum_j^n d_{ij}/n \quad (1),$$

where d_{ij} is the shortest path from location i to j and n represents the total number of locations. The lower the value, the more accessible the location is. Since this is the case, the value for the geographical accessibility will be multiplied by minus 1. If this is not done, then an area that is less accessible would make a greater contribution to the total score of that area. For the geographical accessibility it is not possible to set up a general scoring table, since the score for the geographical accessibility depends on the surrounding locations which are unique for each location.

Delivery reliability

In this research the delivery reliability is measured as the number of on-time and in full deliveries made as a percentage of the total amount of deliveries made (Rao, Rao, & Muniswayy, 2011). Delivery reliability is especially important in areas that solely rely on the delivery of replacements parts. Well-known examples of this area oil rigs and airports. The goal is set to be that 98 per cent of the deliveries is made in full and on time. The equation for delivery reliability is.

$$= \frac{(No. of\ orders\ fulfilled\ on\ time\ \&\ in\ full)}{Total\ No. of\ orders\ fulfilled\ per\ period}$$

The corresponding scores can be seen in the table below.

Delivery reliability	Score
98 %	4
95 – 97 %	3
92 – 94 %	2
90 – 91 %	1
< 89 %	0

Table 5: Delivery reliability scoring index

Life lap

Life lap answers the question on when it the benefits of using UCA can offset the risks involved in using them. Although, life lap is very important in laws and regulations about UCA, it cannot be operationalized and will there not be included in the instrument.

Transportation urgency

Urgency in logistics is defined as the reaction time expressed in time units (van Lon, Ferrante, Turgut, Wenseleers, vanden Berghe & Holvoet, 2015). To my best knowledge, there does not exist a classification for different types of urgency within transportation systems. The classification of the different types of transportation urgencies is as follows.

Transportation urgency	Score
Very urgent	4
---	3
Medium urgent	2
---	1
No urgency	0

Table 6: Transportation urgency index

Area product prices

Area product prices indirectly says something about the remoteness of an area and the way it is connected to other areas. The higher the product prices are, the more geographically remote an area is. Product prices are compared using the Worldwide Cost of Living index (2019). The index assigns a score to each location based on the comparison with a central reference location. The higher the index score the more expensive it is to live in that location. The scoring classification is as follows.

Cost of Living index	Score
< 100	4
101 – 150	3
151 – 200	2
201 – 250	1
> 251	0

Table 7: Product prices Index (Source: https://www.expatistan.com/cost-of-living/index#price-index-explanation)

Facility presence

During this research a number of essential facilities have become known. The score for the factor facility presence depends on the presence of these essential facilities. Since UCA are designed to require as less facilities as possible, the score for facility presence is only based on the presence of the following four facilities, namely a landing strip (with a minimum length of 150m), cargo handling facilities, permission to operate UCA and someone who is qualified to operate a UCA. The scoring classification is as follows.

Facility presence	Score
All four facilities are present	4
Three of the four facilities are present	3
Two of the facilities are present	2
One of the facilities is present	1
None of the four facilities are present	0

Table 8: Facility presence scoring index

Locked economic potential

The economic potential of a region tells something about the potential of a region for economic development and growth. The economic potential of a region is measured using the Economic Potential Index (bAk, 2018). This index shows how well a region is placed within international competition. The index classifies the economic potential of a region in one of the following four options. The scoring classification is as follows.

Economic potential	Score
Very high	4
High	3
Medium	2
Low	1
Very Low	0

Table 9: Economic potential scoring index

Operationalising the selection indicators

After the positive indicators have been operationalised, it is time to operationalise the selection indicators. Selection indicators differ from positive and negative indicators since their value is not important. Selection indicators can either be met (score 1) or not met (score 0).

Minimal transportation distance

Prent (2013) researched the distance for which transportation with UCA is economically optimal. Prent (2013) distinguished between developed – and developing areas. The scores and distances can be found in the table below.

Distance	Score
> 290 km in developing countries	1
> 570 km in developed countries	1
< 290 km in developing countries	0
< 570 km in developed countries	0

Table 10: Minimal Transportation Distance Index

Return freight

According to respondents X and Y (2019), UCA are only flown to those areas where there is also return freight. Respondents X and Y (2019) claim that return freight can decrease the price with 50 per cent. Therefore, the presence of return freight is considered to be necessary to successfully operate UCA.

Return freight	Score
Return freight is present	1
Return freight is not present	0

Table 11: Return freight Index

Life lap

Higher UCA transportation cost and the perceived high risks involved in UCA transportation need to be offset by specific cargo characteristics and thus economic benefits. The cargo needs to have either one of the following characteristics or preferably both. [1] The cargo needs to be highly valuable or [2] the cargo needs to be transported under time pressure. The corresponding scores can be found in the table below.

Added value	Score
High-product value and/or time-bound transportation	1
Low product value and/or transportation time pressure	0

Table 12: Life-lap index

Space to accommodate UCA

Very little space is needed to accommodate UCA. Depending on the type of operation (dropping boxes from a specific altitude vs. landing and unloading), it is expected that UCA do not need more then 150 metres runway (paved or unpaved) to facilitate their operations (PUCA, 2013a).

Space available	Score
> 150 metres	1
< 150 metres	0

Table 13: Space to accomodate UCA index

Trade restrictions

Governments set up trade restrictions to protect domestic trade from foreign competition (Trade restrictions, n.d.). A number of barriers are known to restrict international trade (Trade restrictions, n.d.). [1] Taxes are used for revenue or protective purposes. [2] Import/export quotas are used to limit the amount of goods that can either be imported or exported. [3] non-tariff barriers refer to all kinds of requirements including product requirements and licensing requirements. [4] voluntary export restrictions are agreements made by companies in which they agree to limit their export. The trade restriction scoring classification is as follows.

Trade restrictions	Score
All four restrictions together do not allow the transportation of goods	0
Restrictions do not constitute a barrier to the transportation of goods	1

Table 14: Trade restrictions index

Political factors

Political factors are area specific and include regulations about the use of unmanned cargo aircraft, political stability, in/export regulations, tax policies and trade restrictions (Birnleitner, 2014). This includes the following distribution of scores.

Political factors	Score
Political factors make the transportation of goods impossible	0
Political factors do not constitute a barrier to the transportation of goods	1

Table 15: Political factors index

Accessibility within given travel time or distance

This selection indicator ensures that the distance between two areas can actually be flown by a UCA. In addition, this indicator ensures that the distance can also be flown within given time constraints. The scoring classification is as follows.

Accessibility	Score
Areas cannot be reached within given time and/or distance UCA is capable of flying	0
Areas can be reached within time and distance constraints	1

Table 16: Accessibility index

4.3.1.3 Operationalising the negative indicators

The last group of indicators to operationalize are the negative indicators. In contrast to the positive indicators, a low factor score is most desirable since the summation of all negative scores will later on be subtracted from the summation of all positive scores.

Competitor presence

According to Prent (2013), UCA are likely to be deployed in areas that are currently not served by conventional – or belly freight. Respondent Y (2019) claims the opposite; UCA will be deployed to transport cargo on the same routes as conventional freighter planes do. Because of this contradiction, it is not possible to claim with certainty whether this factor should be positive or negative. For this reason, this factor is not included in the instrument.

Direct connections with other areas

UCA are able to create direct connections between areas that did not exist before (Prent, 2013). Consequently, UCA can create the most benefit if these connections currently do not exist. Here connections are meant direct transportation connections by any means of transport. Areas can be connected via road or rail, through the air or by sea. The less direct transportation routes are located in the area, the more beneficial the deployment of UCA becomes.

Direct connection	Score
Area is currently not connected with other areas by any means of transportation	0
Area is connected by one of the four connections	1

Area is connected by two of the four connections	2
Area is connected by three of the four connections	3
Area is already connected via road and rail, through air, and by sea	4

Table 17: Direct connection index

Noise pollution

Noise pollution is defined as "any unwanted or disturbing noise that interferes or harms humans or wildlife" (Ravi, Jain, Jeremy & Domen, 2016). In this research noise pollution will be measured in terms of dB. The FAA (2018) defined the maximum day and night average noise level to be at 65 dB. The corresponding scores can be found in the table below.

dB	Score
< 65	0
65 – 70	1
71 - 75	2
76 – 80	3
> 80	4

Table 18: Noise pollution index

Population density

The population density is measured as the number of residents per km^2. A classification of the spatial distribution of population density is provided by an article of Chand (2011). He classifies the population density into extreme low density; < 100 persons per km^2, low density; 101 – 250 persons per km^2, moderate density; 251-500 persons per km^2, high density; 501-1000 persons per km^2, very high density; > 1000 persons per km^2. Low density areas are the most attractive for UCA deployment (due to noise pollution and safety risks) and thus receive score 0. Very high densely populated areas receive the score 4.

Area population	Score
< 100 persons per km^2	0
101 – 250 persons per km^2	1
251 - 500 persons per km^2	2
501 – 1000 persons per km^2	3
> 1000 persons per km^2	4

Table 19: Area population index

Area infrastructure quality

The quality of infrastructure (QI) is often measured in relation to the population (POP). The highest QI/POP ratio is observed in Sweden (64.3) whereas the lowest ratio is found in the Dominican Republic (6.7) (Harmes-Liedtke & Jose Oteiza, 2011). The corresponding scores can be found in the table below.

QI/POP	Score
> 55	0
41 - 55	1
26 – 40	2
11 – 25	3
0 – 10	4

Table 20: Quality of infrastructure index

Transportation cost

The exact UCA transportation cost have already been researched by Prent (2013).

UCA transportation cost tend to be higher than transportation associated with different means of transport. UCA transportation cost will be compared to the transportation cost when shipping over sea, by rail or via the road. The corresponding scores can be found in the table below.

Transportation cost	Score
UCA are the cheapest mode of transportation	0
Only rail, road or sea is cheaper than UCA	1
Two modes of transport are cheaper than UCA transportation	2
Only one of sea-, road-, or rail transportation is not cheaper than UCA transportation	3
UCA are the most expensive to transport goods	4

Table 21: Transportation cost index

Transportation time

Just as is the case with the transportation cost, the focus is not on the exact transportation time but rather on the transportation time compared to that of other modes of transport within that same area. The corresponding scores can be found in the table below.

Transportation time	Score
UCA is the fastest mode of transport	0
Only rail-, road- or sea transportation is faster than UCA	1
Two of the transportation modes are faster than UCA	2
Only one of sea-, road-, or rail transportation is slower than UCA transportation	3
Both rail-, road- and sea transportation are faster than UCA transportation	4

Table 22: Transportation time index

Population insecurity

To my best knowledge, there are no scientifically approved methods available with which the population insecurity concerning the use of UCA can be specified. It is expected that the population insecurity increases as the population density also increases. However, no literature is available to support this finding. Therefore, population insecurity will not be included in the instrument.

4.4 Using of the instrument

Sections 4.1 up till 4.3 described the AHP and the GLAM model respectively. In this section the general guidelines on how to use the model will be described. The model is set up in excel and is called 'Area attractiveness assessment instrument'.

The first step to take in using the instrument is to pair wise compare the factors with each other. These comparisons can be done by filling in Comparison matrix ***A*** according to the legend displayed on the right of the matrix. The second step is to check whether the consistency box displayed at the bottom of the worksheet 'Comparison Matrix A' show a number written in green. If this is the case, then the comparisons filled in in matrix ***A*** turn out to be consistent. If this is not the case, then the comparisons will have to be adjusted. Next one should check whether he or she agrees with the eigenvectors that can be seen in the worksheet 'Comparison Matrix A'. These eigenvectors represent the relative importance that is assigned to each factor based on the preferences entered in step one. The fourth step is to assign scores for the area one is interested in. This can be done in the worksheet 'The instrument'. On the right-hand side of this worksheet one can find the factors with the corresponding scores. The area scores can be found using the publicly available data sources described in sections [4.3.1.1, 4.3.1.2, 4.3.1.3]. After the scores were assigned and put into the column 'Absolute', the instrument automatically calculates the area score based on the preferences entered in step one. The final score per area can be found in the worksheet 'The instrument' and is called 'Final score per area'.

4.5 GLAM limitations

The GLAM model uses only indicators of which the value can be found in nationally available GIS-data. This data only reflects on the physical attributes of an area. However, to successfully deploy an UCA in certain areas, much more data is needed. Besides the physical aspects of an area, additional data like type of goods (also area demand), the presence of drone regulations and transportation sustainability/efficiency need to be taken into account. For this exact reason, the GLAM model cannot be applied in its original form. Research has been done to (almost) all indicators and their value using UCA. However, these values are not merged into a central database.

A second limitation to using the GLAM model is the scale on which it is applied. The GLAM model developed by Lankhorst el al. (201) uses grid maps with a resolution of 250 x 250 metres. It would be inefficient to map the whole planet using grid maps this size.

A third limitation of using the GLAM model is the order of magnitude of the factors. This research includes a wide variety of factors. Operationalizing geographical accessibility is a completely different order of magnitude than when the product prices of a region are operationalised.

5. Instrument application

The previous chapters together have led to the development of an instrument that helps the user to make informed decisions with regard to the location of the deployment of UCA. This instrument is the most important deliverable of this research. The development of the instrument has been mainly theoretical. To clarify the added value of the instrument, the use of instrument will be explained in this chapter on the basis of an example. Grootens (2016) determined a suitable area for UCA deployment based on a number of preconditions. Bad infrastructure, low levels of internal air transport and low area occupation led to the conclusion that UCA could be successfully deployed in Alaska, Scandinavian countries, South America and Africa. Grootens (2016) then filters out a number of countries that do not meet the requirements set in its specific business case (medicine transportation). One of the requirements of the instrument developed in this study is that it is generally applicable. For this reason, Karlstad has been chosen to apply the instrument to. Karlstad is located in Sweden and is the capital from the municipality of Karlstad. The place has a little more than 60 thousand inhabitants and can be reached via the road, by rail and through air.

5.1 Instrument application

To apply the instrument, the steps are used as described in section [4.4]. The first step is to pair wise compare the factors with each other. Filling in the pair wise comparison matrix result in an eigenvector per factor. This eigenvalue represents the relative importance of each factor. After carefully filling in the pair wise comparison matrix, the eigenvalues look similar to the ones displayed in Figure 7.

Eigenvector Calculation	Eigenvector (%)
High time value goods presence	7,277804213
Competitor presence	6,58607271
Area prodict prices	6,474158278
Existence of direct connections	4,008697509
Quality of area infrastructure	3,53257652
Transportation cost	4,452877311
Facility presence	6,564800229
Population insecurity	5,523237615
Noise pollution	4,142579394
Population density	7,174861978
Locked economic potential	6,995933508
Geographical accessibility A(G)	6,371012254
Return freight	2,061776081
Transportation urgency	3,700256996
Minimal transportation distance	3,078199182
Trade restrictions	2,928490175
Accessibility within given travel time or distance	3,797540572
Political factors	2,750025958
Life lap	2,701298995
Space to accommodate UCA	4,880464552
Delivery reliability	4,997335969
Total (Sum)	100

Figure 8: Eigenvalue calculation

On the basis of Figure 7 it can be concluded that the presence of high time value goods is the most important factor closely followed by population density and a locked economic potential. A pie chart is used to give the user a better picture of the distribution of the weights per factor. This is shown in Figure 8.

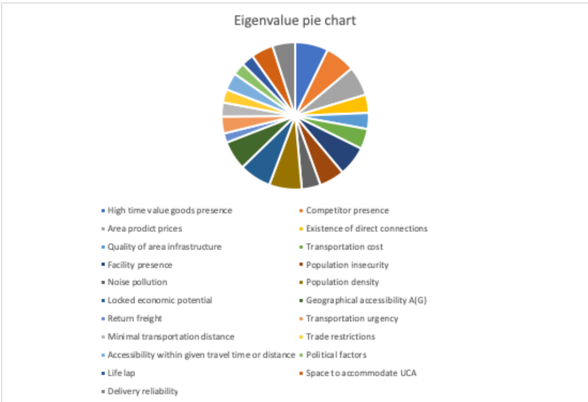

Figure 9: Weight distribution per factor

Next one should check whether or not the comparisons made in the comparison matrix turn out to be consistent. The comparisons are consistent if the value of the consistency ratio stays below 0.10. The consistency ratio calculation can be found at the bottom of the “Comparison Matrix A” worksheet. The consistency ratio for this example is displayed in Figure 9.

Calculating consistency ratio	
CR	2,466737732

Figure 10: Consistency ratio

In this example the consistency ratio is too high, meaning that the comparisons made are not consistent. Normally the user is now requested to review the comparisons made. Since this is an example plus the fact that the weights per factor are an accurate reflection of our preference, the comparisons made earlier have not been revised.

5.1 Positive factors

The next step is to assign scores to the factors with regard to the chosen location Karlstad. To assign scores one should be in the worksheet “The instrument”. In the column ‘Score’ one should fill in the score for the location per factor. Sweden’s main export products are cars, refined petroleum, packed medicines, vehicle parts and trucks (OEC, 2017). All these export products can be classified as valuable, where cars and trucks are not likely to be time sensitive, medicines, petroleum and vehicle parts are. The biggest import products of Sweden are cars and refined petroleum (OEC, 2017). In 2017 the GDP per capita was $50,2 thousands. On this plus the fact that Karlstad has a little over 60 thousand inhabitants, the assumption is based that there is sufficient demand for import products. First a score to the positive factors will be assigned. From the general information provided above, it can be concluded that there are high time value goods present. Thus, the score on this factor is 4. Next follows the calculation of the ‘geographical accessibility’ factor using formula [1]. Karlstad is located between large cities as Stockholm, Oslo and Gotenburg. The distances between these cities and Karlstad can be found in the table below (Google Maps, 2019).

Route	Distance (Km)
Karlstad – Gotenburg	249
Karlstad – Oslo	221
Karlstad – Stockholm	306
Stockholm – Oslo	522
Stockholm – Gotenburg	469
Gotenburg - Oslo	293

Now that the distances between the neighbouring cities is known, the accessibility matrix A(G) can be constructed.

A(G)	K	O	S	G	Sum/n
K	0	221	306	249	194
O	221	0	522	293	259
S	306	522	0	469	324,25
G	249	293	469	0	252,75
Sum/n					1224

Thus, the most acceptable place is Karlstad since it has the lowest summation of all distances. The final geographical accessibility score for Karlstad is -194. The next positive factor to score Karlstad on is the delivery reliability. Delivery reliability is calculated by dividing the total number of orders fulfilled on time and in full by the total number of orders fulfilled per period. Since there is no such information available about transportation using UCA, it is assumed that the delivery reliability in this case is above 98 percent. Thus, Karlstad receives the score 4 on the factor 'delivery reliability'. From the general information provided, it is assumed that both the import and export products need to be transported with very high urgency. For example, medicines need to be transported with high urgency because a person's life can depend on it. Thus, Karlstad scores a 4 on the factor transportation urgency. The score for area product prices can be found by looking up the Cost of Living for Sweden in the Worldwide Cost of Living Index (2019). From three cities in Sweden the Cost of Living Index score is known, all ranging between 160 and 140. For this reason, the Cost of Living Index for Karlstad is assumed to be 150. A Cost of Living Index score of 150 equals a score 3 for the area product prices factor. Successfully operating UCA requires four facilities to be present; landing strip (>150m), cargo handling facilities, permission to operate UCA and an operator. There is an airport to the north-west of Karlstad (Google Maps, 2019). This airport provides the landing strip as well as the cargo handling facilities. Special permission for heavy drones can be obtained in Sweden (UAV Coach, 2014). Since large unmanned cargo aircraft are not operated around Karlstad (yet), it is assumed that there is no UCA operator present in the current situation. Therefore, Karlstad scores 3 on the facility presence factor. Scandinavian regions are top regions as it comes to Economic potential (Economic Potential Index for European Regions, 2018). This is the case because Scandinavian countries have an industry mix with high future potential. The score for the locked economic potential is 4.

Now that all positive indicators have received a score, the Excel tool will indicate a value for the sum of all positive scores multiplied by their relative importance. This is displayed in Figure 10.

Factor/Area	Karlstad	
Positive indicators	Score	Relative
High time value goods	4	0,263442908
Area product prices	3	0,194224748
Facility presence	3	0,120260925
Locked economic potential	4	0,220929505
Geographical accessibility A(G)	-194	-13,9192322
Transportation urgency	4	0,123127967
Delivery reliability	4	0,110001038
Sum (positive)		-12,8872451

Figure 11: Positive indicator score

5.2 Selection indicators

After the positive indicators have received a score, it is time to assign a score to the selection indicators. These indicators can only receive score one and zero. The total score per location, sum of all positive scores minus the sum of all negative scores, is multiplied by the scores on the selection indicators. Thus, score zero on one of the selection indicators means that the total score for a location also equals zero.

The first selection indicator is the minimal transportation distance. A distinction has been made between developed- and developing areas. Normally, a user will have a route to or from a location in mind. Because this is not the case in this example, it is not possible to state whether the route is longer than the required 570 kilometres. A user can simply search for a location further away from Karlstad than 570 kilometres. For this reason, the factor minimal transportation distance receives score 1. The second selection indicator is return freight. In 2017 Sweden exported products with a total value of $143 billion while importing products with a total value of $141 billion. Since the export value is greater than the import value, there is expected to be return freight present in Karlstad. Thus, the score for return freight is 1. The third selection indicator is 'life lap'. Life lap means offsetting the risks involved with UCA transportation by adding enough economic value. Economic value is added when the cargo is highly valuable and/or needs to be transported with high urgency. Both is the case for as well the import- as the export products of Sweden. Therefore, the score for life lap is 1. The fourth selection indicator is 'space to accommodate UCA' and has in fact already been treated in the positive indicator facility presence. The selection indicator 'space to accommodate UCA' receives the score one if there is a landing strip available of more than 150 metres in length. This is the case due to the nearby Karlstad airport. Karlstad receives score 1 on the space to accommodate UCA factor. The next selection indicator is trade restrictions. Four possible restrictions can limit the trade to and from a location. To my best knowledge, there is no information available about the trade restrictions in Karlstad. For this reason, there has not been assigned a score to this selection indicator. The penultimate selection indicator is political factors. Political factors are intended to indicate whether the country is politically stable enough to transport cargo to and from. According to the Political Stability Index (2017), Sweden scores 0,98 and thus can be seen as political stable since the worldwide average in 2017 was -0,05. As indication, Monaco had the highest value with 1,65 whereas Yemen scored the lowest with a value of – 2,96 (GlobalEconomy.com, 2017). Thus, Karlstad receives score 1 on the political factors. The last selection indicator is the accessibility within a given travel time or distance. This selection indicator checks whether the planned route can be flown by UCA with regard to the distance (range), the cargo that has to be transported (payload), and the time it takes to complete the flight. Assuming that the flight is planned so that all three requirements are met, Karlstad receives score 1 for this selection indicator.

In the Microsoft Excel, after filling in the scores for the selection indicators, the tool looks like Figure 11.

Selection indicators		
Return freight	1	0,020617761
Minimal transportation distance	1	0,030781992
Trade restrictions	N.D	#WAARDE!
Accessibility within given time or distance	1	0,037975406
Political factors	1	0,02750026
Life lap	1	0,02701299
Space to accommodate UCA	1	0,048804646

Figure 12: Selection indicators score

5.3 Negative indicators

The last indicators to score the location on are the negative indicators. The sum of the scores of all negative indicators will be subtracted from the sum of the scores of all positive indicators.

The first negative indicator is the presence of competitors. Prent (2013) concluded that UCA are most beneficial when used in areas where there is little competition. This is the case because other modes of transport, for example rail or sea transportation, are often cheaper than UCA transportation. However, during the expert interviews it turned out that UCA will only operate in areas where competitors also operate. In this way, UCA will fly with certainty on routes where there is sufficient cargo to transport. Because it is not clear whether competition is beneficial or not, no score will be assigned to this factor. However, the possibilities for competition must be reviewed. This is done by looking at how the location is connected to surrounding locations. The better the location is connected to the environment, the less likely UCA is to add value to the transportation network. Karlstad is connected through air, via road and by rail (Wikipedia, 2018). For this reason, Karlstad scores 3 on 'the direct connections with other areas' factor. The third negative indicator is noise pollution. The FAA (2018) set the maximum day and night noise level at 65 dB. The exact amount of noise UCA will produce is not known yet. Literature indicates that UCA will produce noise and that governments have to take actions to reduce these noise levels (KiM, 2017). It is assumed that the noise levels produced by UCA are between the 71 and 75 dB. For this reason, Karlstad scores 2 on noise pollution. The next negative factor Karlstad is scored on is 'population density'. The population density for any world regions can be simply looked up with the help of the World Population Density Map (2019). The average population density of Karlstad is between the 5.5 and 7.5k residents per square kilometre. This corresponds to score 4 for the population density factor. The next negative factor is the area infrastructure quality. A database called TCdata360 (2017) contains all quality of overall infrastructure scores per region. Sweden scores 5.63 which corresponds with score 3 on the area infrastructure quality factor. Today no large UCA are flying around yet. Therefore, UCA transportation cost can only be estimated. This estimate can be used to determine how high the transport costs are compared to other means of transport. Prent (2013) concluded that belly transportation and transportation by truck are cheaper than UCA transportation. Since Karlstad is not connected by sea, sea transportation is not an option. Two modes of transport are cheaper than UCA transportation corresponding with score 2 on the transportation cost factor. The last negative factor Karlstad should be scored on is population insecurity. However, there is no method available with which the population insecurity can be measured. Literature mentions two main reasons for population insecurity to increase regarding the deployment of UCA, namely safety and privacy issues (Dulo, 2015). The first one is a possible violation of the privacy of an individual. The second risk is the risk of UCA being hijacked and used for terrorist purposes. A possible measurement for the population insecurity for Karlstad can be done by distributing a survey. Till then, Karlstad cannot be scored on the population insecurity factor.

After all the scores for the negative indicators have been filled in, the tool displays the final score for the chosen location. This is shown in Figure 12.

Negative indicators		
Competitor presence	N.D	0
Existence of direct connections	3	0,120260925
Quality of area infrastructure	3	0,105977296
Transportation cost	2	0,089057546
Population insecurity		0
Noise pollution	2	0,082851588
Population density	4	0,286994479
Final score per area		**-0,68514183**

Figure 13: Total location score

As can be seen in Figure 12, the total score for Karlstad is a negative number. This is so because it is not possible to operationalize the geographical accessibility for all locations in the world. Therefore, the greater the distance between a location and its surrounding locations, the more negative the final score for that location will be. No conclusions can be drawn from this score. This score can serve as comparison material when trying to determine the score of other locations. The purpose of this chapter was to provide users with an example of how to use the instrument. Some of the required data can be obtained from online accessible databases while other data must be obtained by logical reasoning.

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6. Conclusion

In this research an answer to the following question had to be found: 'How can we address the viability of an area for unmanned cargo aircraft deployment?' To be able to answer this research question, qualitative research has been conducted about area attractiveness with regard to unmanned cargo aircraft deployment.

From the theoretical revision a number of factors were extracted. These factors do influence the attractiveness of an area regarding the deployment of a new transportation system in that area. However, the completeness of this list of factors is not certain. For this reason, the list has been discussed with experts in the field of unmanned cargo aircraft deployment. It turned out that the list compiled on the basis of the literature had to be changed on a number of points. This led to the following conclusion. *The attractiveness of an area for unmanned cargo aircraft deployment can be determined on the basis of 23 factors.*

Given the broad definitions of these 23 factors, all-encompassing different elements, defining a level for these factors was not easy. The factors have been subdivided into positive, negative and selection indicators. The three subgroups could then be combined into one level. Positive indicators could either be assigned scores 4 up to 0, negative indicators could be assigned scores 0 up to 4 and selection indicators could only be assigned either 1 or 0.

The interviews showed that users all have different preferences with regard to the aforementioned factors. To take this subjectivity into account, the users' preferences are passed on to a relative weight per factor.

This qualitative study has shown that the viability of an area for unmanned cargo aircraft deployment requires the area to be scored on 23 factors of which the relative importance has been determined based on the users' preferences.

Besides the main research question, this study also attempted to answer the sub-research questions. The sub-research questions with their answers, based on the content provided in this research, follow below.

[1] According to the literature, which factors can potentially influence the attractiveness of an area?

The literature provided a number of factors that at least have a causal relationship with the variable 'area attractiveness'. This list can be found in Figure 3.

[2] *What are the most important characteristics of unmanned cargo aircraft?*

Research about the benefits of UCA over manned cargo aircraft has already been conducted extensively. Besides benefits due to the physical properties of unmanned cargo aircraft, benefits can also be achieved from the way in which UCA are deployed. Both physical property – and deployment benefits have been described in Table 1 and Table 2 respectively.

[3] *How can the quality of the list be determined?*

[3,1] How can the correctness of the list be established?

[3,2] How can the double-counts be determined?

[3,3] How can the consistency be determined?

The quality of the list has been discussed in section [3.3]. Zowghi and Gervasi (2002) described three C's on the basis of which the correctness, completeness and consistency of a list of factors could be determined. Informal proof of the quality of the list has been discussed in the subsections [3.3.1] up to [3.3.3]. Correctness of the list of factors has been insured by documenting the factors accurately. It was decided to work with the detailed elaboration in which all factors were still present. Some factors are made up of several sub-factors. However, these have not been taken into consideration because not all factors are made up of sub-factors. In addition, the correctness has been established by verifying the factors using the book Geen probleem (2012). Only those factors that have influence on the main variable area attractiveness have been taken into account. The completeness of the list of factors cannot be determined with certainty. Research about unmanned cargo aircraft and their deployment location is still evolving. It is therefore logical to assume that increasingly more factors will become known in the (near) future. The consistency of the factors has been insured by removing duplicate and/or mutually exclusive factors. A number of factors described the same phenomenon but were defined differently. These factors have been removed from the list. No mutually exclusive factors were present in the list. However, there are a number of factors in the list that reinforce each other and/or cannot exist without each other. An example of this is given by population density and noise pollution. The higher the population density, the greater the noise pollution.

[4] *What factors influence the area attractiveness according to members of PUCA?*

Interviews with two members of the Platform Unmanned Cargo Aircraft revealed a number of factors which until then could not be found in the literature. Besides this, new insights were gained as a result of these interviews. Prent (2013) concluded that competitors cannot be present for UCA to be able to be feasible within an area. In contrast, respondent Y claimed that competitors must be present. Respondent Y substantiated this statement by arguing that UCA will not fly on routes where there is currently no cargo transportation. Consequently, the factor competitor presence is not taken into consideration since it is not clear into which category this factor should be classified (positive or negative). In conclusion, the most important result of the interviews has been supplementing the information from the literature.

7. Discussion

In this chapter recommendations for future analysis will be made based on this study. Since relatively little research has been done about UCA, the number of future studies is almost inexhaustible. This chapter provides an overview of the most logical follow-up studies.

7.1 Future research

This study provides an overview of the factors needed to assess the attractiveness of an area with regard to UCA deployment. These factors, together with their relative importance change over time. Sustainability, for example has become increasingly important in recent years. Fuel price is an example of a factor whose value is subject to rapid change. Because more and more literature becomes available about UCA, the number of factors that must be included in the analysis also increases. The final attractiveness score for a location is based on 21 factors. For this reason, the conclusion is very uncertain and probably not generally accepted. To increase applicability, more factors will have to be added. However, adding more factors brings multiple problems. First, adding more factors causes the comparison between two factors to cause inconsistency. Secondly, adding more factors reduces the differences in relative importance between the factors.

7.2 Technical changes

A number of technical changes must be made to the model in order to make the outcome more accurate. Due to time constraints, these changes have not been implemented. However, they will be discussed briefly below. It is possible that one of the 21 factors has no value at all for an user. In the current version, this factor will nevertheless have a small relative importance. A change in the model has to be made, which allows the user to select which factors should be included in the analysis.

An optional but not required extension could be to perform the analysis per available UCA model. The score per area on a number of factors will also depend on the UCA model that is used for the analysis. Transportation cost and transportation time depend on both the vehicle being used and the other means of transport in the area. Also, some UCA models will require more or less space to be accommodated. Because this adjustment will only lead to minor changes in scores, it is not mandatory to implement.

A shortcoming of the current model is that the databases needed to score certain factors only have the information per country. As can be seen in the case study in chapter 5, often data for Sweden is used. For this reason, a way must be found to convert the data per country to data for a specific location. However, this will be very time-consuming and inefficient.

7.3 Non-technical changes

To be able to use the model, assumptions need to be made about the value of the transportation cost and transportation times of unmanned cargo aircraft. These assumptions are based on information that is currently present. It could be very well that these values change in the future. Because UCA still carry low volumes of cargo, their transportation cost is relatively high. If the laws and regulations about the use of large unmanned cargo aircraft will be approved, this means that larger freight volumes can be transported by UCA, which will reduce transport cost.

7.4 How to proceed from here

First, the consistency of the comparisons between two factors in the model must be improved. If the pair wise comparisons do not yield a consistent matrix, then the final conclusion on what area to deploy UCA in will not be accepted by the users of the model. Secondly, this research tried to ensure the validity of the instrument by enlarging the variety of factors that influences the area attractiveness. To be absolutely sure that the instrument is valid, additional tests will have to be performed. Correlation tests will have to be performed to determine whether two variables can actually be included in the model as separate variables or not.

it has been tried to make the variety of factors as large as possible. By including even more factors, the chance of measuring what is actually to be measured, increases. Adding more factors can be done by increasing the number of interviews with experts in the field of UCA deployment. As there is currently no consensus on which factors determine the area attractiveness with regard to the deployment of unmanned cargo aircraft, a Delphi-study must be performed in order to reach consensus via a number of iterations about the factors that determine the area attractiveness. By questioning the findings of this research within a large audience, it is possible to prevent a one-sided vision of the subject from arising.

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Appendix A. Interview questions

1. In your opinion, what factors determine the attractiveness of an area regarding unmanned cargo aircraft deployment?

An instrument is going to be developed that helps its users in making an informed decision about where to deploy their unmanned cargo aircraft. This instrument should be transparent in the sense of that it is known where all the underlying information is coming from. Also, the instrument should be repeatedly applicable so that it can be used also in the future.

2. In your opinion, what should the lay-out of the instrument look like?

3. What decision making rule should be used to assess the importance of each of the indicators mentioned in question one?

Appendix B Interview Respondent X

Interview 1: respondent X. Held: 27-03-19 at 17:13 by phone.

A. Area attractiveness regarding unmanned cargo aircraft deployment

1. In your opinion, what factors determine the attractiveness of an area regarding unmanned cargo aircraft deployment?

At my former job I did research on what routes would be attractive to transport pallets on using UCA. For this research I had to know what commodities would be suitable to be transported using UCA. I came to the conclusion that the commodities need to have at least the following characteristics in order to be suitable for transportation by UCA.

First of all, it is important that the commodities have high added value. If the commodities do not add enough value, then transporting them using UCA would be too expensive. Added value can be generated in multiple ways. For example, added value is generated when food products are transported. Food products are perishable and therefore need to be transported quickly. Another time essential product is medicines. Most of the time medicines are crucial for the good health of a person and are therefore transported fast. Besides goods being time efficient, goods can add value by being very valuable. Valuable products, machinery parts for example, are suitable for transportation by air.

Secondly return freight determines whether or not an area is suitable for UCA deployment. Return freight can halve the price of a flight. It is easy to look for areas where you can transport products from point A to point B. However, this gets very hard when point B also has to have return fright.

A third factor determining whether or not an area is viable for UCA deployment is formed by the quality of the infrastructure present. Transportation by air can create more value if the ground structure is in bad condition.

A fourth advantage of using air transport is the delivery reliability. Especially when the ground infrastructure is not that good, air transport becomes more attractive due to the high delivery reliability.

If we take all these factors into account, we usually end up in rural areas. Rural areas, like Scandinavia, Greenland, Iceland or Australia have less cities per amount of area then for example Europe. In areas with high infrastructure density, like Europe, often the quality of the ground infrastructure is very good making it impossible for UCA transport to compete with this. In Africa for example, all that is transported via air is better than when it would be transported via road. The UCA advantage becomes bigger in rural areas since they are able to deliver the products directly from the fabricant to the user.

An instrument is going to be developed that helps its users in making an informed decision about where to deploy their unmanned cargo aircraft. This instrument should be transparent in the sense of that it is known where all the underlying information is coming from. Also, the instrument should be repeatedly applicable so that it can be used also in the future.

2. In your opinion, what should the lay-out of the instrument look like?

The instrument should be easy to use without the need of too much guidance. The model should look simple and clear. The model should be general applicable, meaning that there is something built in which lets users represent their own preferences. This can be done by, for example offering the opinion to rule out factors that are not important to some users.

3. What decision making rule should be used to assess the importance of each of the indicators mentioned in question one?

Since the indicators mentioned in question one, are qualitative of nature, they need to be quantified in some sort of way. In this quantification a trade-off between the infrastructure density of an area and the deployment of UCA could be made. This trade off can be described using some sort of mathematical model. A rough outcome of this model should be that highly dense urban areas are less attractive for UCA deployment. This because these areas often have good ground infrastructure which makes road transportation much cheaper than transportation via air using UCA. The model should show that rural areas without good infrastructure are attractive to deploy UCA in. Besides these rural areas, also Islands are very attractive since these areas are not directly accessible via the ground. The UCA point-to-point delivery can add its maximum value in these cases.

Appendix C Pair wise comparison matrix A (1)

Comparison matrix A	High time value goods p	Competitor presence	Area prodict prices	Existence of direct conn	Quality of area infrastru	Transportation cost	Facility presence	Population insecurity	Noise pollution	Population density	Locked economic potent
High time value goods p	**1**	9	1/9	5	7	1	9	1/7	1/5	1/3	7
Competitor presence	1/9	**1**	1/9	1/3	5	9	1/7	5	7	1/3	5
Area prodict prices	9	9	**1**	1/7	5	7	5	1/9	5	1/5	1/3
Existence of direct conn	1/5	3	7	**1**	9	3	1/9	3	1/5	1/9	1/7
Quality of area infrastru	1/7	1/5	1/5	1/9	**1**	5	1/9	5	1/9	1/7	1/7
Transportation cost	1	1/9	1/7	1/3	1/5	**1**	1/9	3	1/3	1/3	1/3
Facility presence	1/9	7	1/5	9	9	9	**1**	1/7	5	1/5	1/5
Population insecurity	7	1/5	9	1/3	1/5	1/3	7	**1**	1/7	1/5	1/3
Noise pollution	5	1/7	1/5	5	9	3	1/5	7	**1**	1/5	1/7
Population density	3	3	5	9	7	3	5	5	5	**1**	1/7
Locked economic potent	1/7	1/5	3	7	7	3	5	3	7	7	**1**
Geographical accessibili	5	1/3	1/5	9	1/7	1/7	7	5	3	3	7
Return freight	3	1/3	1/5	1	1/5	1/9	1/5	1/3	1/5	1/3	1/3
Transportation urgency	1/9	1/9	7	1/5	3	1	1/3	1/3	1/5	1/7	1/9
Minimal transportation	1/9	1/3	1/3	1/3	9	7	1/3	1/3	1/5	1/3	1/3
Trade restrictions	5	1/7	1/7	7	1/7	1/7	1/7	1/7	3	1/7	1/7
Accessibility within give	1/3	1/9	3	1/9	9	1/9	1/9	1/9	3	1/9	1/5
Political factors	1	1/9	1/9	3	1/9	1/9	1/9	1/9	5	1/9	5
Life lap	1/9	1	1	1	1	1	1	1	5	1	1
Space to accommodate	3	1	1	1	1	1	1	1	1	5	1
Delivery reliability	3	1/5	5	3	3	1/9	1/9	1/7	3	1/5	7
Total (Sum)	**47 3/8**	**36 1/2**	**44**	**62 8/9**	**86**	**55**	**43**	**41**	**54 3/5**	**20 3/7**	**36 8/9**

Appendix C Pair wise comparison matrix A (2)

Geographical accessibili	Return freight	Transportation urgency	Minimal transportation	Trade restrictions	Accessibility within give	Political factors	Life lap	Space to accommodate	Delivery reliability
1/5	1/3	9	9	1/5	3	1	9	1/3	1/3
3	3	9	3	7	9	9	1	1	5
5	5	1/7	3	7	1/3	9	1	1	1/5
1/9	1	5	3	1/7	9	1/3	1	1	1/3
7	5	1/3	1/9	7	1/9	9	1	1	1/3
7	9	1	1/7	7	9	9	1	1	9
1/7	5	3	3	7	9	9	1	1	9
1/5	3	3	3	7	9	9	1	1	7
1/3	5	5	5	1/3	1/3	1/5	1/5	1	1/3
1/3	3	7	3	7	9	9	1	1/5	5
1/7	3	9	3	7	5	1/5	1	1	1/7
1	3	1	3	1/5	1/9	9	1	1	7
1/3	**1**	3	1/3	7	9	1/7	1	1/7	1/5
1	1/3	**1**	3	7	9	9	1	1	7
1/3	3	1/3	**1**	7	1/5	9	1/7	1/7	7
5	1/7	1/7	1/7	**1**	9	1/3	1	1	1/7
9	1/9	1/9	5	1/9	**1**	9	1	1	5
1/9	7	1/9	1/9	3	1/9	**1**	1	1/5	5
1	1	1	7	1	1	1	**1**	1/5	1
1	7	1	7	1	1	5	5	**1**	1/7
1/7	5	1/7	1/7	7	1/5	1/5	1	7	**1**
42 3/8	**70**	**59 1/3**	**62**	**91**	**93 2/5**	**108 2/5**	**31 1/3**	**22 2/9**	**70 1/6**

Appendix D Normalized Matrix A (1)

Standardized matrix	High time value goods p	Competitor presence	Area prodict prices	Existence of direct conn	Quality of area infrastru	Transportation cost	Facility presence	Population insecurity	Noise pollution	Population density	Locked economic potent
High time value goods p	0,0211	0,2464	0,0025	0,0795	0,0814	0,0182	0,2092	0,0035	0,0037	0,0163	0,1897
Competitor presence	0,0023	0,0274	0,0025	0,0053	0,0581	0,1634	0,0033	0,1222	0,1282	0,0163	0,1355
Area prodict prices	0,1900	0,2464	0,0228	0,0023	0,0581	0,1271	0,1162	0,0027	0,0916	0,0098	0,0090
Existence of direct conn	0,0042	0,0821	0,1593	0,0159	0,1047	0,0545	0,0026	0,0733	0,0037	0,0054	0,0039
Quality of area infrastru	0,0030	0,0055	0,0046	0,0018	0,0116	0,0908	0,0026	0,1222	0,0020	0,0070	0,0039
Transportation cost	0,0211	0,0030	0,0033	0,0053	0,0023	0,0182	0,0026	0,0733	0,0061	0,0163	0,0090
Facility presence	0,0023	0,1916	0,0046	0,1431	0,1047	0,1634	0,0232	0,0035	0,0916	0,0098	0,0054
Population insecurity	0,1478	0,0055	0,2048	0,0053	0,0023	0,0061	0,1627	0,0244	0,0026	0,0098	0,0090
Noise pollution	0,1055	0,0039	0,0046	0,0795	0,1047	0,0545	0,0046	0,1711	0,0183	0,0098	0,0039
Population density	0,0633	0,0821	0,1138	0,1431	0,0814	0,0545	0,1162	0,1222	0,0916	0,0490	0,0039
Locked economic potent	0,0030	0,0055	0,0683	0,1113	0,0814	0,0545	0,1162	0,0733	0,1282	0,3427	0,0271
Geographical accessibili	0,1055	0,0091	0,0046	0,1431	0,0017	0,0026	0,1627	0,1222	0,0550	0,1469	0,1897
Return freight	0,0633	0,0091	0,0046	0,0159	0,0023	0,0020	0,0046	0,0081	0,0037	0,0163	0,0090
Transportation urgency	0,0023	0,0030	0,1593	0,0032	0,0349	0,0182	0,0077	0,0081	0,0037	0,0070	0,0030
Minimal transportation	0,0023	0,0091	0,0076	0,0053	0,1047	0,1271	0,0077	0,0081	0,0037	0,0163	0,0090
Trade restrictions	0,1055	0,0039	0,0033	0,1113	0,0017	0,0026	0,0033	0,0035	0,0550	0,0070	0,0039
Accessibility within give	0,0070	0,0030	0,0683	0,0018	0,1047	0,0020	0,0026	0,0027	0,0550	0,0054	0,0054
Political factors	0,0211	0,0030	0,0025	0,0477	0,0013	0,0020	0,0026	0,0027	0,0916	0,0054	0,1355
Life lap	0,0023	0,0274	0,0228	0,0159	0,0116	0,0182	0,0232	0,0244	0,0916	0,0490	0,0271
Space to accommodate	0,0633	0,0274	0,0228	0,0159	0,0116	0,0182	0,0232	0,0244	0,0183	0,2448	0,0271
Delivery reliability	0,0633	0,0055	0,1138	0,0477	0,0349	0,0020	0,0026	0,0035	0,0550	0,0098	0,1897
Total (Sum)	**1,0000**	**1,0000**	**1,0000**	**1,0000**	**1,0000**	**1,0000**	**1,0000**	**1,0000**	**1,0000**	**1,0000**	**1,0000**

Appendix D Normalized Matrix A (2)

Geographical accessibili	Return freight	Transportation urgency	Minimal transportation	Trade restrictions	Accessibility within give	Political factors	Life lap	Space to accommodate	Delivery reliability	Total (Sum)
0,0047	0,0048	0,1517	0,1452	0,0022	0,0321	0,0092	0,2871	0,0150	0,0048	**1,5283**
0,0708	0,0429	0,1517	0,0484	0,0769	0,0964	0,0830	0,0319	0,0450	0,0713	**1,3831**
0,1180	0,0715	0,0024	0,0484	0,0769	0,0036	0,0830	0,0319	0,0450	0,0029	**1,3596**
0,0026	0,0143	0,0843	0,0484	0,0016	0,0964	0,0031	0,0319	0,0450	0,0048	**0,8418**
0,1652	0,0715	0,0056	0,0018	0,0769	0,0012	0,0830	0,0319	0,0450	0,0048	**0,7418**
0,1652	0,1287	0,0169	0,0023	0,0769	0,0964	0,0830	0,0319	0,0450	0,1283	**0,9351**
0,0034	0,0715	0,0506	0,0484	0,0769	0,0964	0,0830	0,0319	0,0450	0,1283	**1,3786**
0,0047	0,0429	0,0506	0,0484	0,0769	0,0964	0,0830	0,0319	0,0450	0,0998	**1,1599**
0,0079	0,0715	0,0843	0,0807	0,0037	0,0036	0,0018	0,0064	0,0450	0,0048	**0,8699**
0,0079	0,0429	0,1180	0,0484	0,0769	0,0964	0,0830	0,0319	0,0090	0,0713	**1,5067**
0,0034	0,0429	0,1517	0,0484	0,0769	0,0535	0,0018	0,0319	0,0450	0,0020	**1,4691**
0,0236	0,0429	0,0169	0,0484	0,0022	0,0012	0,0830	0,0319	0,0450	0,0998	**1,3379**
0,0079	0,0143	0,0506	0,0054	0,0769	0,0964	0,0013	0,0319	0,0064	0,0029	**0,4330**
0,0236	0,0048	0,0169	0,0484	0,0769	0,0964	0,0830	0,0319	0,0450	0,0998	**0,7771**
0,0079	0,0429	0,0056	0,0161	0,0769	0,0021	0,0830	0,0046	0,0064	0,0998	**0,6464**
0,1180	0,0020	0,0024	0,0023	0,0110	0,0964	0,0031	0,0319	0,0450	0,0020	**0,6150**
0,2123	0,0016	0,0019	0,0807	0,0012	0,0107	0,0830	0,0319	0,0450	0,0713	**0,7975**
0,0026	0,1001	0,0019	0,0018	0,0330	0,0012	0,0092	0,0319	0,0090	0,0713	**0,5775**
0,0236	0,0143	0,0169	0,1129	0,0110	0,0107	0,0092	0,0319	0,0090	0,0143	**0,5673**
0,0236	0,1001	0,0169	0,1129	0,0110	0,0107	0,0461	0,1595	0,0450	0,0020	**1,0249**
0,0034	0,0715	0,0024	0,0023	0,0769	0,0021	0,0018	0,0319	0,3150	0,0143	**1,0494**
1,0000	**1,0000**	**1,0000**	**1,0000**	**1,0000**	**1,0000**	**1,0000**	**1,0000**	**1,0000**	**1,0000**	**21,0000**

Appendix E Eigenvector calculations (1)

Eigenvector Calculation	Row total/n	Eigenvector
High time value goods presence	0,072778042	7,277804213
Competitor presence	0,065860727	6,58607271
Area prodict prices	0,064741583	6,474158278
Existence of direct connections	0,040086975	4,008697509
Quality of area infrastructure	0,035325765	3,53257652
Transportation cost	0,044528773	4,452877311
Facility presence	0,065648002	6,564800229
Population insecurity	0,055232376	5,523237615
Noise pollution	0,041425794	4,142579394
Population density	0,07174862	7,174861978
Locked economic potential	0,069959335	6,995933508
Geographical accessibility A(G)	0,063710123	6,371012254
Return freight	0,020617761	2,061776081
Transportation urgency	0,03700257	3,700256996
Minimal transportation distance	0,030781992	3,078199182
Trade restrictions	0,029284902	2,928490175
Accessibility within given travel time or distance	0,037975406	3,797540572
Political factors	0,02750026	2,750025958
Life lap	0,02701299	2,701298995
Space to accommodate UCA	0,048804646	4,880464552
Delivery reliability	0,04997336	4,997335969
Total (Sum)	**1**	**100**

Appendix E Eigenvector calculations (2)