Expansion of Arlanda Terminals

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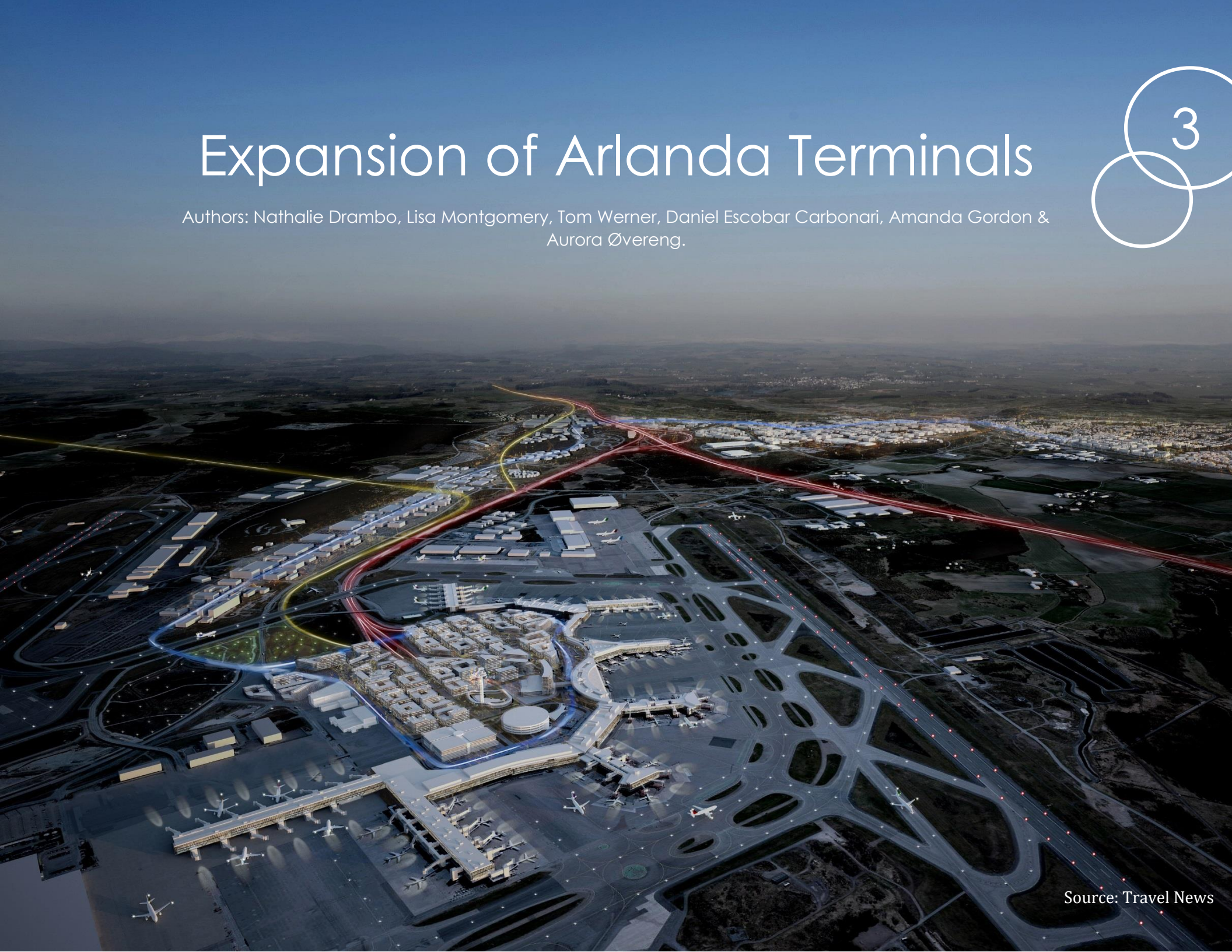

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Non-technical summary

Introduction

Because of an expected increase in air travels, Swedavia is currently planning an expansion of Stockholm-Arlanda Airport. Their aim is to have a capacity of 70 million yearly passengers by 2067, which is around three times the amount of passenger today. If this vision is to become reality, it is important to assess the impacts, effects and consequences of the expansion on the environment. Consequently, this environmental impact assessment (EIA) aims to do so. It will focus on the two alternatives for terminal expansion presented by Swedavia in their Draft Masterplan from 2017. Other than these two alternatives, the EIA will also look at a zero alternative that explains what will happen to the environment if the project is not carried out. Lastly, we will present our recommendation for which alternative is preferable in regard to the environment.

Background

Air travel at Arlanda has increased with 40 per cent over the past six years, with 23 million passengers passing through the airport in 2015. Because of this, a first step to expand Arlanda began in 2014. This first step is a development programme called Utvecklingsprogram Arlanda (UPA), and it is expected to last until 2023, creating a total capacity of 35 million yearly passengers. Other than the UPA, no formal decisions on expansion have currently been made.

Economic growth, along with other external factors, have contributed to Swedavia's realisation that the earlier Masterplan from 2014 is outdated. Instead, a new (Draft) Masterplan has been developed, which was presented in 2017. The Draft Masterplan presents strategies for Arlanda to become the leading Scandinavian airport and regional transport node.

Arlanda Airport is classified as a national interest and also includes a relatively large area of land outside the central, operational area. As a national interest, Arlanda is protected against change that would prevent or diminish the airport's operations. Future expansion will most likely require that the boundaries for the national interest area are moved. Since Arlanda officially opened in 1962, several expansions have taken place, and today the airport has four terminals: 2, 3, 4 and 5. Prior to UPA, Arlanda had 350 000 m^2 of terminal area. For a capacity of 70 million yearly passengers, Swedavia has calculated that this area will need to be doubled. The two alternatives proposed for future expansion in the Draft Masterplan include developing the existing terminal structure (Alternative Central) or constructing a new terminal building in an unexploited area (Alternative North). Three additional alternatives have already been identified and

dismissed by Swedavia, because they did not meet the required demands.

The Alternatives

Alternative Central - this alternative focuses on an expansion of the existing terminals, and also includes new buildings and piers for aircrafts.

Alternative North - this alternative proposes a new terminal building in a largely unexploited area north of Arlanda.

Zero Alternative – this alternative looks at possible effects and consequences if neither of the other two alternatives are carried out. It does, however, include the UPA expansion.

Current situation

Of the land occupied by Arlanda Airport, airside constitutes 9 km^2 and landside 5 km^2. The boundary between the two is normally considered to be the airport security check. Landside is the more accessible area for passengers and members of the public, whereas airside is fenced in.

The airport creates job opportunities, but also generates waste and various usage of water. Areas of forest and farmland are in close vicinity to the airport, and there are also a number of sites of historical and/or cultural interest. These areas are mainly affected by noise and air pollution, but also by pollution in lakes and other bodies of water.

The central parts of airside and landside are mainly consistent of hard surfaces with various types of infrastructure. The logistics and cargo area is located at the southern end of the terminal buildings. To the southeast of existing terminals is a hangar housing a collection of historic aircrafts called Arlanda Flygsamlingar. The area north of Arlanda is largely coniferous forest and bedrock, and is home to a nature reserve called Laggatorp. West of the forest, in connection with Runway 1, is an area of grassland. East of the forest is a closed extraction site that is part of the Stockholm esker. The site is currently used as a motocross track. All three of the mentioned areas north of Arlanda have natural values, and are more or less unusual in the landscape today; on a local, regional and national level.

Comparison of alternatives

Both Alternative Central and Alternative North will impact the environment. That said, Alternative North has a more direct, physical environmental impact, which includes land-use change. Depending on the alternative chosen, and how it is carried out, certain aspects of the environmental impacts can be mitigated. An expansion also provides opportunity for Arlanda to become more efficient, with less impact on the environment than it has today.

The advantage of Alternative Central over North is that it will be developed on already built surfaces. It would mean taking land that has previously been exploited, and making it more efficient. In terms of biodiversity, Arlanda acts as a barrier in the landscape. This is a negative effect that needs to be reduced. Alternative North would heighten this effect. In addition, Alternative North would lead to a loss of habitat and a reduced ability for the landscape to provide ecosystem services. A potential conflict with Laggatorp nature reserve is a risk with this alternative, and should be avoided. In summary, the effects of Alternative North collide with the national environmental objectives. An expansion in the north also requires more extensive solutions for ground transportation, as well as additional infrastructure for this and

other operations. It has not been possible to prove that any environmental gain will come from Alternative North. The Zero Alternative includes UPA, and is not expected to have significant environmental impact.

The removal of land in Alternative North could generate a great amount of particles in the air, as would the use of heavy machinery for construction. If activities were to be prohibited during high winds, and the on-site speed of construction vehicles limited, it could reduce the generation of particles. It is also suggested that dust suppressants are used in unpaved areas. While on a smaller scale, these mitigation measures also apply to Alternative Central.

The main source of CO_2 emissions when constructing a new terminal would be the diesel engines used in construction vehicles. Same applies to emissions of ozone and nitrogen dioxide. In order to reduce these emissions, focus needs to be on making equipment more efficient, and developing alternative fuel sources. However, since there will always be some CO_2 emissions when diesel engines are used, compensation through carbon certified credits could be necessary.

Both Alternative North and Central will likely have to deal with greater amounts of stormwater, due to the increase in hard surface area. For this to be handled properly, it is important that careful planning and assessment of future conditions are implemented prior to development. In terms of groundwater, the Stockholm esker needs to be monitored, to establish change in flow or quantity. Groundwater is mainly affected by chemicals used in construction and maintenance, such as de-icing of airplanes. Therefore, efforts should be made to find ways of lessening the amount of chemicals that find their way into the water.

Waste is generated at any construction site, making a major development like a terminal expansion a significant source of various types of waste. To minimize the risk of foreign object debris, it is recommended that a protective fence is set up around the construction site. Also, to avoid construction waste going to landfills, materials should be reused and/or recycled wherever possible. If multiple entrepreneurs are involved it is even more important to ensure this is done in a streamlined manner. During operation, focus should be on minimizing and recycling all types of waste. Waste management should be considered at the planning stage, in particular in Alternative North, since there is possibility to incorporate it in the terminal design.

To lessen the impact on Laggatorp nature reserve if Alternative North is carried out, it is important that the new terminal building is constructed at sufficient distance, and preferably a low height. If the exploitation physically affects Laggatorp nature reserve, then compensatory measures has to be taken. This would mean a new nature reserve has to be established, or the existing can be extended. Furthermore, in order to avoid damage to ecosystem services an analysis of such services should be performed. In addition, to ensure that no harm comes to undiscovered cultural historic sites, it is recommended that a thorough archaeological survey is carried out prior to development. In Alternative Central there may be a need to expand further south in the future, which would require Cargo City to move. The impacts of this have not been assessed here, but is significant to consider nonetheless. Care should also be taken to preserve the historical collection of aircrafts at Arlanda Flygsamlingar, which could be threatened by

an expansion to the southeast in Alternative Central. However, with the construction of a new terminal there is great opportunity to highlight Swedish aviation history, as well as developing new cultural experiences, something which is relevant to bear in mind.

An expansion of Arlanda would not only impact the environment but, as Sweden's main airport, it would also greatly affect the socio-economic conditions. Here, we have only assessed the impacts on a local scale, namely Arlanda terminals. Even so, they are dominantly positive. Both construction and operation of a new terminal would create more job opportunities. Additional security-checks, customs and baggage handling systems would likely contribute to greater customer satisfaction, as would an aesthetically pleasing terminal building. Furthermore, an increase in air travels could mean more economic benefits for the region (and nation), but that lies beyond the scope of this chapter.

Conclusion

Even though many of the impacts apply to all alternatives, they do so to a varied degree. Because the proposed site in the north is largely unexploited, the level of impact on some environmental components are significantly higher in Alternative North. The conclusion is therefore, that, other than the Zero Alternative, Alternative Central is least harmful to the environment and is therefore recommended for expanding the terminals at Stockholm-Arlanda Airport.

Icke-teknisk sammanfattning

Inledning

Med anledning av det ökade antalet flygresor planeras en utbyggnad av Arlanda. Målsättningen är att kunna hantera 70 miljoner årliga passagerare år 2067, vilket är tre gånger dagens antal. Om denna vision ska bli verklighet är det viktigt att expansionens påverkan, effekter och konsekvenser på miljön utreds och analyseras. Denna miljökonsekvensbeskrivning avser göra detta för de två expansionsalternativ som presenterats i Swedavias utkast för framtida utbyggnad från 2017. Utöver det utreds även ett nollalternativ, det vill säga vad som händer om utbyggnaden inte sker. Slutligen ges ett förslag om vilket alternativ som utifrån ett antal miljöaspekter kan anses vara det mest fördelaktiga.

Bakgrund

De senaste sex åren har antalet flygresor från och till Arlanda ökat med cirka 40 procent. År 2015 var passagerarantalet omkring 23 miljoner. Sedan 2014 pågår Utvecklingsprogram Arlanda (UPA) som planlagt vägar för en kapacitetsökning till 35 miljoner passagerare årligen. Utvecklingsprogrammet sträcker sig till 2023. Utöver UPA har det inte tagits några formella beslut för en vidare utbyggnad.

Ekonomisk tillväxt, tillsammans med andra externa faktorer har bidragit till att Swedavia anser att den tidigare Masterplanen från 2014 är inaktuell. 2017 arbetade Swedavia fram ett utkast till en ny Masterplan. Masterplanen presenterar strategier för Arlanda att bli Skandinaviens ledande flygplats samt regional transportknutpunkt.

Arlanda är klassat som riksintresse och inkluderar även ett relativt stort område mark utanför det operativa, centrala flygplatsområdet. Riksintresset innebär ett skydd mot förändringar som skulle kunna hindra eller försvåra flygplatsverksamheten. En framtida expansion kommer dock sannolikt kräva att gränsen för riskintresseområdet flyttas. Sedan Arlanda öppnade 1962 har flera utbyggnader skett och idag finns fyra terminaler: 2, 3, 4 och 5. Innan UPA var den totala terminalytan 350 000 $m_{2.}$ Med 70 miljoner årliga passagerare beräknar Swedavia att terminalytan behöver dubblas till 700 000 m^2.

De två terminalutbyggnadsalternativen som föreslås i utkastet till Masterplanen är antingen en utbyggnad av de befintliga terminalerna - Alternativ Central, eller en helt ny terminal i ett nytt område av flygplatsen - Alternativ Norr. Utöver dessa har tre

andra geografiska alternativ identifierats. Dessa har dock avfärdats då de inte uppfyllt de formulerade kraven.

Alternativ
Alternativ Central inkluderar endast utbyggnad av det befintliga terminalområdet. Detta inkluderar även nya byggnader samt pirer för flygplan.

Alternativ Norr inkluderar en ny terminal i ett nytt, till största delen oexploaterat område i Arlandas norra del.

Nollalternativet visar på möjliga effekter och konsekvenser om inget av de två alternativen väljs, och en expansion utöver UPA uteblir.

Nulägesbeskrivning
Arlanda flygplats består av två huvudsakliga områden, *airside* och *landside*. *Airside* utgörs främst av landningsbanor samt övriga områden avsedda för flygplanstrafik. Runtom finns ett område som benämns *landside*. Detta område utgör flygplatsen mer tillgängliga del, med byggnader och olika faciliteter samt kommunikationer med bil, buss och tåg.

Flygplatsen skapar arbetstillfällen men också olika typer av avfall och användning och påverkan av grund- och ytvatten. Utanför *landside* tar skogs- och jordbrukslandskap vid. Här finns även fornlämningar. Detta område påverkas i första hand av buller och luftföroreningar men också i viss mån genom förorening av sjöar och vattendrag.

De centrala delarna av *airside* och *landside* består till övervägande del av hårdgjorda ytor med olika typer av infrastruktur. Här finns också Arlanda Flygsamlingar, där en kollektion av äldre flygplan finns bevarade. Området norr om Arlanda består framförallt av skogsmark. En mindre del utgörs av Laggatorp naturreservat med hällmarkstallskog. Västerut finns gräsmarker och i den östra delen av Arlanda finns en nedlagd grustäkt som är en del av Stockholmsåsen. I täkten, som idag är en motorkrossbana, finns höga naturvärden.

Alla de tre ovannämnda typerna av värdefull natur i området norr om Arlanda är idag mer eller mindre ovanliga inslag i det omgivande landskapet. Trots att både gräsmarkerna och grustäkten är skapade genom mänsklig aktivitet är de viktiga att värna om. De bidrar på olika sätt till det artrika men idag minskande öppna landskapet. De bevuxna områdena är en viktig spridningskorridor for många arter. All typ av natur utgör dessutom en viktig förutsättning för en del av de olika ekosystemtjänster som människan är beroende av. Det omgivande landskapet är viktigt på lokal, likväl som regional och nationell skala.

Jämförelse mellan alternativ
Både Alternativ Central och Alternativ Norr kommer att medföra miljöpåverkan av olika slag. Alternativ Norr har dock en mer direkt, fysisk miljöpåverkan med ändrad markanvändning och ingrepp i landskapet som följd. Beroende på vilket alternativ som väljs och hur det utformas, kan vissa aspekter av miljöpåverkan minskas. En expansion ger också möjlighet för Arlanda att bli effektivare, med mindre inverkan på miljön än idag.

Den huvudsakliga fördelen med Alternativ Central är att flygplatsverksamheten expanderar på ett område som redan idag används i liknande syfte, vilket medför en effektivisering av redan ianspråktagen mark. När det gäller biologisk mångfald fungerar Arlanda som ett hinder i landskapet. Detta är en negativ effekt som behöver minskas. Alternativ Norr förvärrar denna effekt. Vidare leder en exploatering av Alternativ Norr en förlust av viktiga livsmiljöer samt en minskad förmåga för landskapet att tillhandahålla ekosystemtjänster. En potentiell konflikt med Laggatorp naturreservat är en risk med detta alternativ som bör undvikas. Sammanfattningsvis står Alternativ Norr i konflikt med de nationella miljömålen. En expansion i norr kräver också mer omfattande lösningar för marktransporter, samt ytterligare infrastruktur för denna och andra verksamheter. Det har inte varit möjligt att bevisa att någon miljövinst kommer att komma från Alternativ Norr. Nollalternativet omfattar UPA, och förväntas inte ha betydande miljöpåverkan.

Borttagandet av mark i Alternativ Norr kan potentiellt generera en stor mängd partiklar i luften, vilket användandet av tunga byggmaskiner också gör. Utifall att sådana aktiviteter förbjuds under tider med hård vind, och att byggfordonens hastighet på plats sänks kan partikeluppkomsten minskas. Ytterligare förslagsåtgärd är att använda dammbindande medel på grusvägar och andra liknande underlag. Dessa mildrande åtgärder gäller även för Alternativ Central.

Den största källan till koldioxidutsläpp vid konstruktion av en ny terminalyta är de dieselmotorer som används i byggfordon. Detsamma gäller för utsläpp av ozon och kvävedioxid. För att minska dessa utsläpp måste fokus vara på att använda alternativa bränslekällor. Eftersom det emellertid alltid kommer att finnas några koldioxidutsläpp när dieselmotorer används kan koldioxidkompensation vara nödvändig.

Både Alternativ Norr och Central kommer sannolikt att behöva hantera större mängder dagvatten på grund av en ökning i antalet hårdgjorda ytor.

För att detta ska hanteras på ett bra sätt är det viktigt att noggrann planering och bedömning av framtida förhållanden genomförs innan utbyggnaden. När det gäller grundvatten bör Stockholmsåsen övervakas för att fastställa förändringar i flöde eller tillgång. Grundvatten påverkas främst av kemikalier som används vid konstruktion och underhåll, t.ex. avisning av flygplan. Därför bör ansträngningar göras för att hitta sätt att minska mängden kemikalier som letar sig ner till grundvattnet.

Avfall genereras på alla byggplatser, vilket gör en stor utveckling som en terminalexpansion blir betydande källa till olika typer av avfall. För att minimera risken för skador från främmande föremål rekommenderas att ett skyddsstängsel upprättas runt byggarbetsplatsen. För att undvika att byggavfall går till deponi bör materialet återanvändas och/eller återvinnas där det är möjligt. Om flera byggentreprenörer är involverade är det ännu viktigare att se till att detta sker på ett effektiviserat sätt. Under drift ska fokus läggas på minimering och återvinning av alla typer av avfall. Avfallshantering bör övervägas i planeringsstadiet, särskilt i Alternativ Norr, eftersom det finns möjligheter att införliva det i terminaldesignen.

För att minimera påverkan på Laggatorp naturreservat om Alternativ Norr utförs är det viktigt att den nya

terminalbyggnaden är uppförs på tillräckligt avstånd från reservatet. Om exploateringen har en fysisk påverkan Laggatorp naturreservat måste kompensationsåtgärder vidtas. Det skulle innebära att ett nytt naturreservat måste etableras, eller att det befintliga kan förstoras. För att undvika skador på ekosystemtjänsterna bör dessutom en analys av sådana tjänster utföras. För att säkerställa att ingen skada uppstår på oupptäckta kulturhistoriska platser, rekommenderas det att en grundlig arkeologisk undersökning utförs före utbyggnad. I Alternativ Central kan det finnas behov av att expandera ytterligare söderut i framtiden, vilket skulle kräva att Logistikterminalen kan behöva flyttas. Effekterna av detta har inte utvärderats här, men det är viktigt att överväga. Försiktighet bör också vidtas för att bevara den historiska samlingen av flygplan hos Arlanda Flygsamlingar, vilket kan hotas av en eventuell utbyggnad mot sydost i Alternative Central. Men med byggandet av en ny terminal finns det samtidigt bra möjligheter att lyfta fram den svenska luftfartshistorien, samt att utveckla nya kulturupplevelser, något som är relevant för att tänka på.

En utbyggnad av Arlanda påverkar inte bara miljön, utan som största flygplats i Sverige påverkar Arlanda också i hög grad de socio-ekonomiska förhållandena i regionen som helhet. I denna miljöbedömning har effekterna på lokal skala endast utvärderats. Trots detta är den övervägande utvecklingen positiv. En utbyggnad av flygplatsverksamheter, och då framförallt en utökad terminalstruktur, skulle skapa fler arbetstillfällen. Ytterligare säkerhetskontroller, tull- och bagagehanteringssystem skulle sannolikt bidra till ökad kundnöjdhet, liksom en estetiskt tilltalande terminalbyggnad. Dessutom kan en ökning av antalet flygresor betyda mer ekonomiska fördelar för regionen (och Sverige som helhet), men det ligger utanför ramen för detta kapitel.

Slutsats

Även om många av miljöeffekterna gäller för båda alternativen, gör de det i varierande grad. Eftersom att den förslagna platsen för expansion i norr är i stort sett outnyttjad är påverkan betydligt större i Alternativ Norr jämfört med Alternative Central. Slutsatsen är därför att Alternativ Central är att rekommendera för en framtida expansion av terminalerna vid Stockholm-Arlanda Airport eftersom att det är minst skadligt för miljön.

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3.1 Introduction

Sweden's accessibility within and outside its national borders is largely dependent on the quality and size of Stockholm-Arlanda Airport. The airport is currently expanding, with a goal of reaching a capacity of 40 million travellers in 2040 (Swedavia, 2017a). Based on the long-term strategic objectives for Swedavia, the future vision for Arlanda is an airport that can accommodate nearly 70 million yearly travellers by 2067 (Swedavia, 2017b). Such a development places high demands on the existing terminal structure. In addition, the potential closing of Bromma Airport might lead to even higher number of air travels to and from Arlanda. Thus, there would be a need to increase both the traveller and airplane capacity by expanding the terminal and airplane stand area.

In 2017, a Draft Masterplan was produced to show the possibilities for future expansion of Arlanda Airport (Swedavia, 2017b). The economic growth and change in external factors have created a need for updating the previous Masterplan from 2014. By developing and extending the terminal infrastructure, a greater number of travellers can pass through Stockholm-Arlanda Airport each year.

At the time of writing, no final decisions have been made. Thus, this chapter intends to identify development alternatives and propose recommendations for expanding the Arlanda terminal area, including the airplane stand area. However, such an expansion does not come without its consequences. By conducting an environmental impact assessment, the environmental impacts of the planned development of the airport terminals can be identified and analysed. The purpose of the environmental impact assessment is to, more closely, investigate each of the proposed expansion alternatives. This is done from a long-term environmentally sustainable perspective, where the provision of mitigating measures will be included, with the aim of contributing to a potential development of a world-leading green airport.

3.1.1 Aim and research question

The overall aim of this chapter is to investigate the environmental and socio-economic implications of an expansion of Arlanda terminals. This involves identifying, interpreting and communicating impacts associated with the construction and operation phase of the proposed expansion.

In addition, this chapter aims to highlight the following questions: what are the main environmental impacts of different development alternatives? With respect to the environmental implications and spatial demands, which alternative is most suitable?

3.2 Boundaries

This section describes the geographical and temporal boundaries set for this chapter.

3.2.1 Geographical boundaries

The area of investigation for this environmental impact assessment is Stockholm-Arlanda Airport. Arlanda is located between the cities Stockholm and Uppsala in Sigtuna municipality. The distance to the central parts of Stockholm is approximately 40 kilometres (Swedavia, 2015).

The airport area consists of a fenced area named *airside,* and an area just outside which is called *landside*. The airside covers almost 9 km^2, and includes runways 1, 2 and 3 (Vatten & Samhällsteknik, 2011). The area also includes various airline operations. Swedavia owns most of the airside buildings and facilities.

Landside covers almost 5 km^2 and contains a number of buildings and facilities affiliated with airport operations. These include ground transportation such as buses, taxis and cars. Travellers to Arlanda that are not coming in by airplane first pass through the landside area. External companies dominate most of the operations on landside.

Increasing the amount of airplane stands will only affect the airside area, whereas an expansion of the terminal building will affect both the landside and airside area. According to Swedavia (2013a), the limit between landside and airside is at the security-check and the fences surrounding the runway area. This separation concept emphasizes a physical separation of facilities that handle passengers and ground vehicles, and those that primarily deal with aircraft handling.

Due to the fact that impacts such as noise and air quality will be investigated, the spatial boundaries need to be widened. As such the spatial boundaries are set to be equal to the Arlanda area of national interest, including its influence area of noise. This area comprises of the entire airport. It also includes areas that, today or within an immediate future of about 50 years, may be exposed to airborne noise over the legal threshold level. The influence area also takes into account expanding Arlanda with a fourth runway.

Lastly, this chapter will solely consider the geographical locations for the expansion alternatives identified in the Arlanda Masterplan (Swedavia, 2017b). This is due to the scoping process not identifying any other viable alternatives. The main focus will be on a central and a northern alternative for locating a new terminal area.

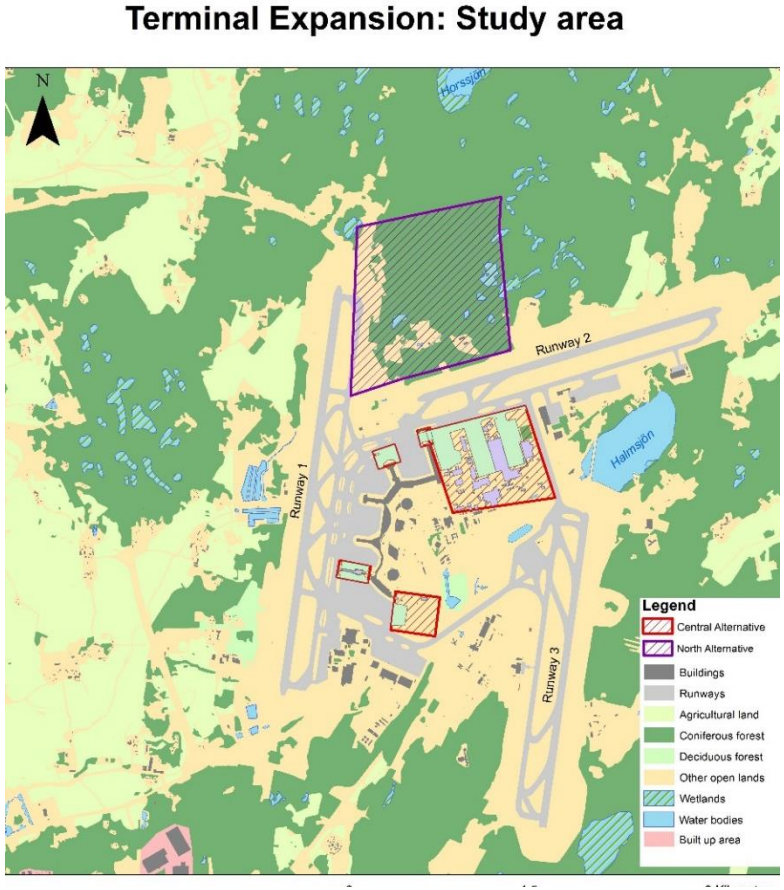

Figure 3.1. Map over the study area, including the geographical location for Alternative Central and Alternative North. Data collected from Lantmäteriet (Carbonari & Øvereng, 2017).

3.2.2 Temporal boundaries

The time boundary for our study will be based on future prognosis for air travellers from Stockholm-Arlanda Airport, including passengers transferring at Arlanda. Thus, we will not have a determined end year, but rather look at viable alternatives and impacts depending on the desired traveller capacity. Swedavia has set the time horizon for the Draft Masterplan to 2067, since by that time they picture it reasonable to reach 70 million travellers (Karelis *et al*. 2017, personal communication, November 30). With respect to this, we will not include occurrences beyond that year.

In this chapter we will distinguish between the time of construction and the time of operation. This does mainly affect the way we address the impacts, which can vary over the life cycle of a proposed development (Glasson *et al*. 2013). We do not take into account impacts occurring under the decommissioning phase, since we do not see that happening in the near future.

Finally, we want to highlight that setting time boundaries always involve making trade-offs between level of impact assessment, and their development over time, and uncertainty (Lucic *et al*. 2015). With a more limited time frame, the level of uncertainty decreases. Studying a project such as the expansion of terminals at Arlanda Airport requires an extended time frame, since more relevant impacts and more feasible development alternatives can then be addressed.

3.2.3 Scoping

During the scoping exercise for this chapter we decided on the main significant impacts that we will address and analyse further. The impacts are shown in Table 3.1.

Table 3.1. Identified environmental impacts.

Environmental aspects	Description
Land use	According to OECD (1997) provides information on the land cover and the human activities involved in use of the land.
Air quality	The Oxford Dictionary (2017a) refers to air quality as the degree to which the air is free from pollutions. The pollutants that will determine the air quality in the area are the presence of carbon monoxide, nitric dioxide, sulphur oxides, lead, ground level ozone and particles.
Hydrology and water use	We refer to both surface runoff and water usage. Surface runoff is defined as water from impervious surfaces caused by human activities that is allocated elsewhere (USGS, 2016). Water usage refers to the total amount of water withdrawn from a source and used somewhere else (Reig, 2013).
Noise	Defined as a sound that is loud or unpleasant in way that it causes disturbances (Oxford dictionaries, 2017b). In this chapter we will only investigate noise from construction of the terminals.
Waste	Defined by Business Dictionary (2017) as unwanted material or material discharged to, or deposited in, the environment. In this chapter we refer to waste as leftover materials placed in trash bins or being recycled.
Cultural heritage	Is a wide concept that generally refers to visible and tangible traces from antiquity to the recent past. Cultural heritage can be built environments, natural environments and artefacts with a historical value (Feather, 2006).
Socio-economic	Relates to impacts in socio-economic factors. In this chapter we will examine job opportunities and security.

3.3 Methods

One of the main purposes of an environmental impact assessment is to understand the potential environmental consequences of a given action, project or measure (Wood, 2003). The process in which impacts are assessed can be subdivided into two main phases: impact identification and impact evaluation (Glasson *et al*. 2013). In the following section the methods used in order to derive information regarding the environmental consequences of the proposed expansion of Arlanda Airport terminals is explained.

3.3.1 Checklists

The method used for the first stage of this EIA, impact identification, was the checklist. This method is based on a list of special biophysical, social and economic factors that may be affected by a development (Glasson *et al*. 2013). This simple method generates guidance to the EIA, allowing the analysis to focus on the most important environmental concerns.

The checklist was constructed by doing a literature review of environmental impact assessments done for other international airports. Analysing examples is helpful in identifying the main environmental topics considered in the development of an airport. Nevertheless, most of the EIAs consulted were carried out for complete airports in which the terminal was only a part of the analysis.

For the checklist of impact identification, nine environmental impact assessment reports were analysed. From the nine airports, three were from Africa, three from Asia and the other three were from Europe. The oldest analysis is from 1998 and the newest from 2015. The checklist includes all the environmental aspects or values that were subject to analysis in these reports. The overall value represents the number of times that an environmental aspect is included across the nine examples analysed.

The results are organised from the most common environmental aspect to the least common, and are presented in Table 3.11 in Chapter 9.3 (Appendix). In the literature, 24 environmental aspects or values were identified. Each environmental value has a score from 1 to 9, depending on the number of EIA reports they appear in. The maximum score is 9 since that is the number of EIAs included in the literature review.

For a given environmental value to be considered important, it was decided it should have a threshold of 6 or above in the overall value. Based on these criteria, the environmental values or aspects identified to be important for the current study were air quality, noise and surface water with an overall value of 8. Transportation had a value of 7, while land uses changes, cultural heritage and socio-economics had a value of 6. The other 17 environmental aspect or values were discarded for the present study through this method. Transportation, which commonly includes aspects related to traffic, is also discarded because it is outside the boundaries of what an airport terminal implies.

According to the previous analysis, the impacts identified in the scoping phase, and that are going to be assessed and evaluated for the present study, are presented in Table 3.1. The effects that are going to be assessed are also presented.

3.3.2 Interviews

None of the impact identification methods are flawless. It is therefore recommended to use different approaches to be able to identify the most important environmental impacts. On

November 30, 2017, the team had the opportunity to exchange ideas with representatives from Swedavia. The information presented included the overview of the environmental plans and goals regarding Arlanda and other Swedavia operations. Based on the exercise, impacts previously not identified as important were assessed again.

GHG emissions and waste were identified as important impacts, and will be included among the ones previously acknowledged. In the case of the GHG emissions, there is a goal of zero net emissions in all Swedavia´s operations, which include Arlanda airport. Swedavia is committed to being a carbon neutral company, and it has been since 2006 (Swedavia, 2016a). This is aligned with the national goal of the Swedish government of reaching zero net emissions by 2045. The expansion of the terminal might cause indirect and direct GHG emissions both in the construction phase and in the operation phase. From new electric and heating demand to the new materials, building and operating a big airport terminal can have an impact on climate change (Lucon *et al*. 2014).

Waste is also an important issue. The increasing amount of people and the requirements for materials during the construction and operation will surely increase the amount of waste produced at Arlanda. After the meeting with Swedavia, it was clear that there are on-going efforts to increase the quality of waste management. The construction of a big building such as a terminal could put some extra pressure on the waste management programme of Arlanda Airport. Also, the increasing amount of people in the airport means more consumption and use of many different materials, and therefore more waste. Calculating the amount of waste, and ways to approach this problem, could lead to detection and reduction of an important environmental impact.

After using two methods for impact identification, a checklist based on literature review and interviews with stakeholders, the complete list of environmental impacts and effects was finalised. This is presented in Table 3.1.

Active stakeholder participation was desired for the EIA process. However, due to time constraints this was not possible. Nevertheless, the information given by Swedavia at the start of the process was valuable.

3.3.3 Causal Loop Diagram

Early in the EIA process, during scoping, we constructed a Causal Loop Diagram (CLD). We used this method as an impact identification method together with the matrix. The CLD was also used to identify the direct and indirect casualties of the project. During the EIA process the CLD has been revised due to changes in boundaries. The CLD has been divided into construction phase and operation phase, this is because the different phases will have different impacts on the environment. The CLD is a great tool to use for seeing the direct and indirect impacts. However, it cannot define the impacts as significant or insignificant, or the magnitude of them. Causal Loop Diagrams is widely used within systems thinking. To create a CLD you need (1) unique variables (2) causality and (3) delays. The blue boxes (Figure 3.2, Figure 3.3) represents the identified environmental impacts. The plus and minus describes whether there is a change in respectively the same or opposite direction. The hash marks are used when there is a time delay. In the construction phase (Figure 3.2), the time delays are not defined.

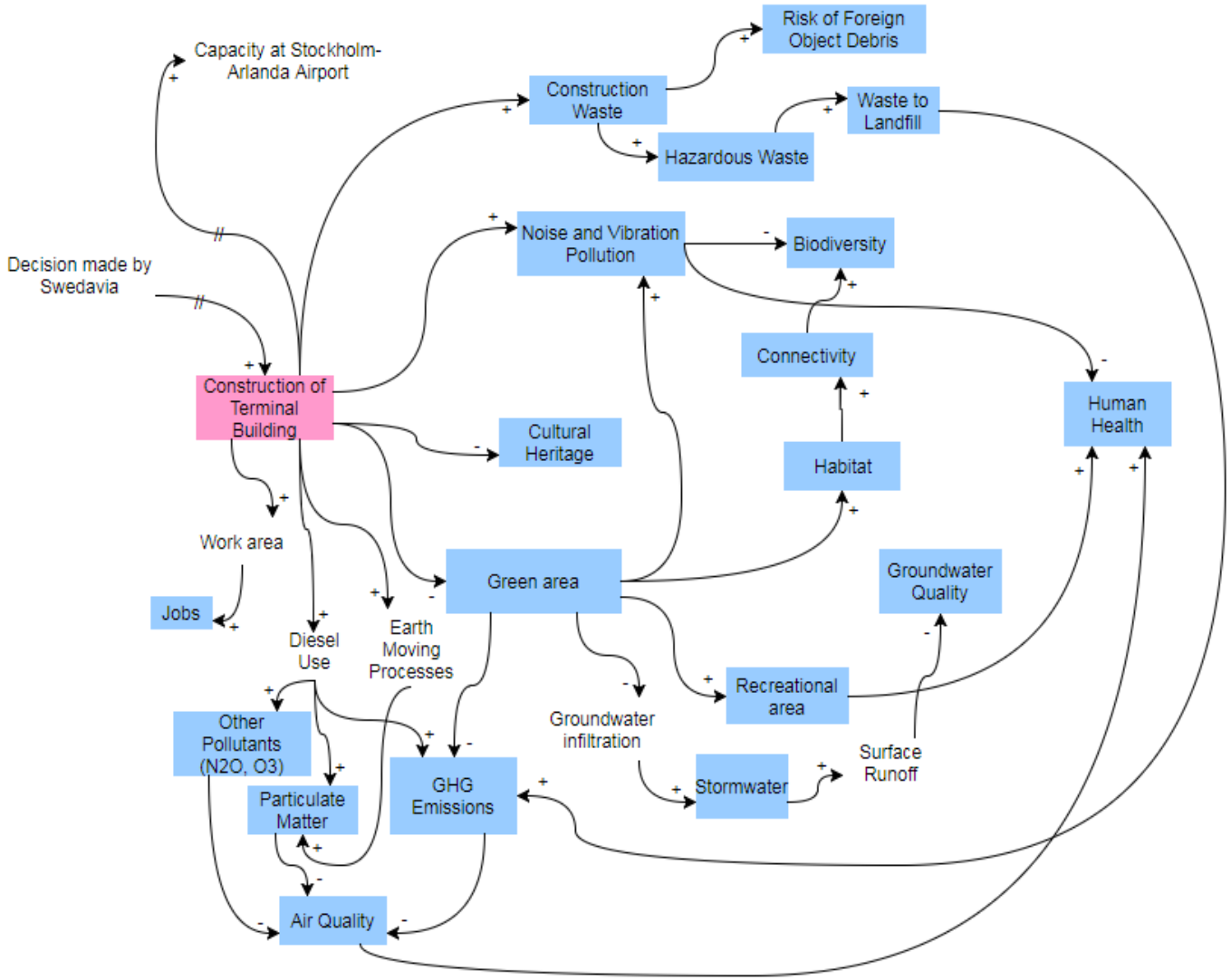

Figure 3.2. Causal Loop Diagram for Construction Phase. The blue boxes represent the identified environmental impacts. The plus (+) means change in the same direction and the minus (-) means change in the opposite direction.

Construction Phase

Decision made by Swedavia leads to *Construction of Terminal*, with a delay.

Construction of Terminal leads to more *Construction Waste*. More Construction waste leads to both higher risk of *Foreign Object Debris.* More *Construction Waste* also leads to more *Hazardous Waste* which leads to more *Waste to Landfill*.

More *Construction of Terminal* leads to more *Noise and Vibration Pollution* which in turn leads to less *Biodiversity* and less *Human Health*.
More Construction of Terminal leads to less *Cultural Heritage*. *More Construction of Terminal* leads to less *Green Area*, which leads to more *Noise and Vibration Pollution*. Less *Green Area* also leads to less *Habitat*, which leads to less *Connectivity*. Less *Connectivity* leads to less *Biodiversity*.

Less *Green Area* leads to less *Recreational Area* which leads to less *Human Health*. Less *Green Area* also leads to less *Groundwater infiltration* which in turn leads to more *Stormwater*. More *Stormwater* leads to more *Surface Runoff* which leads to less *Groundwater Quality*. Lastly, less *Green Area* leads to more *GHG concentration*, which leads to less *Air Quality.*

More *Construction of Terminal* leads to more *Earth Moving Processes*, which leads to more *Particulate Matter*. More *Particulate Matter* leads to less *Air Quality*. Less *Air Quality* leads to less *Human Health.*

More *Construction of Terminal* also leads to more *Diesel Use*, more *Diesel Use* leads to more *Particulate Matter*, more *Other Pollutants* and more *GHG Emissions*. More *Construction of Terminal* leads to more *Work area* which leads to more *Jobs*. Lastly, more *Construction of Terminal* leads to more *Capacity at Stockholm-Arlanda-Airport* with a delay (which in this case is construction time).

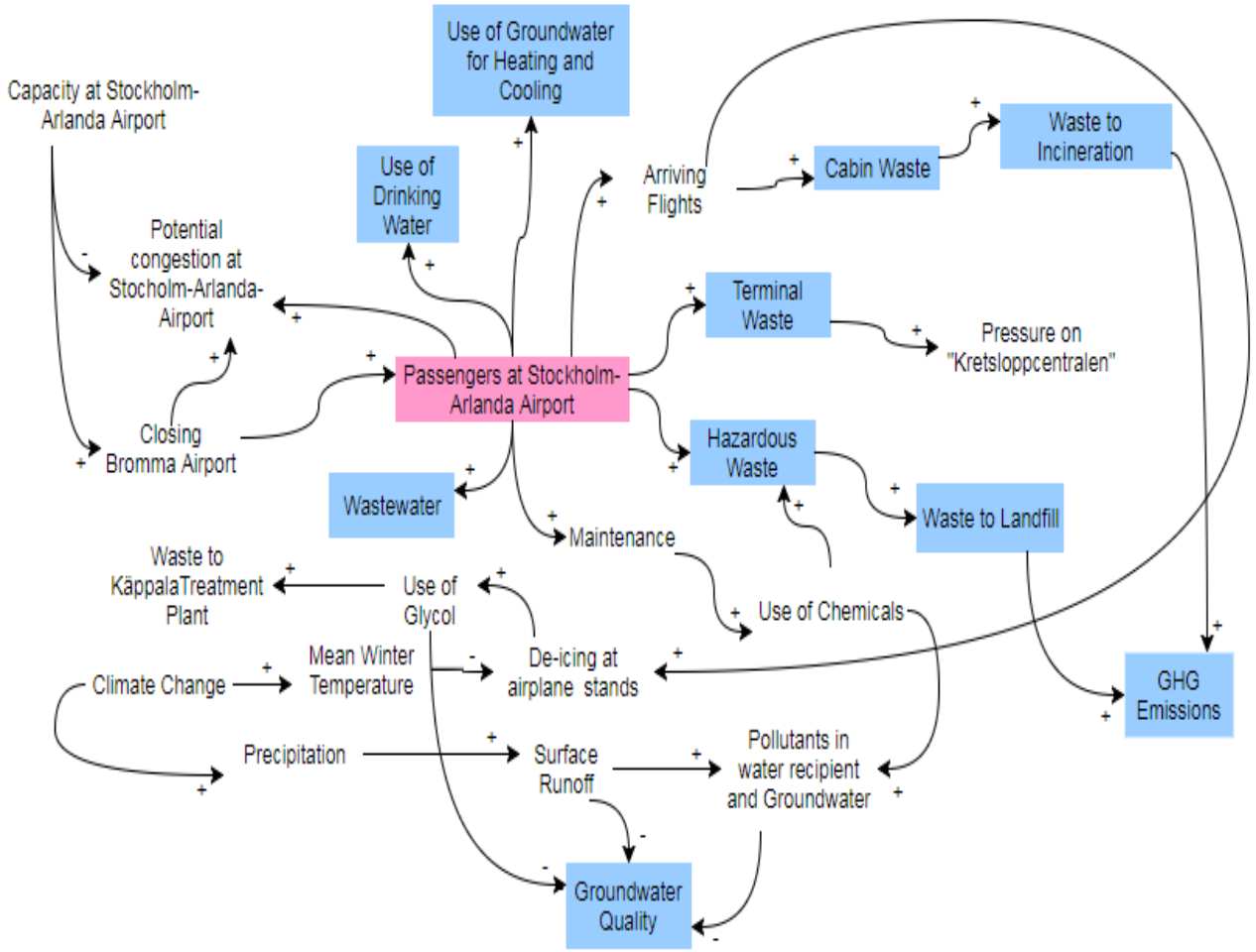

Figure 3.3. Causal Loop Diagram for the Operation Phase. The blue boxes represent the identified environmental impacts. The plus (+) is change in the same direction, and minus (-) is change in the opposite direction.

Operation Phase

Passengers at Stockholm-Arlanda Airport leads to more *Drinking Water Use. Passengers at Stockholm-Arlanda-Airport* leads to more *Use of Groundwater for Heating and Cooling of Terminal Building.*

Passengers at Stockholm-Arlanda Airport leads to more *Arriving Flights*, which leads to more *Cabin Waste* which further leads to more *Waste to Incineration.* More *Arriving Flights* also leads to more *De-icing at airplane stands*

Passengers at Stockholm-Arlanda Airport leads to more *Terminal Waste*, this leads to more *Pressure on "Kretsloppcentralen". Passengers at Stockholm-Arlanda-Airport* leads to more *Hazardous Waste*, which leads to more *Waste to Landfill.*

Passengers at Stockholm-Arlanda Airport leads to more *Maintenance* which leads to more *Use of Chemicals*, which in turn leads to more *Hazardous Waste.* More *Use of Chemicals* leads to more *Pollutants in water recipient and Groundwater.* More *Pollutants in water recipient and Groundwater* leads to less *Groundwater Quality.*

More *Climate Change* leads to more *Precipitation* which leads to more *Surface Runoff. More Surface Runoff leads* to more *Pollutants in water recipient and Groundwater and less Groundwater Quality.* More *Climate Change* also leads to higher *Mean Winter Temperature*, this leads to *less De-icing at airplane stands.* Less *De-icing at airplane stands* leads to less *Use of Glycol* and further less *Waste to Käppala Treatment Plant.*

Passengers at Stockholm-Arlanda Airport leads to more *Wastewater*. *Passengers at Stockholm-Arlanda-Airport* leads to more *Potential congestion at Stockholm-Arlanda-Airport. Closing Bromma Airport* leads to more *Potential congestion at Stockholm-Arlanda-Airport.*

Closing Bromma Airport also leads to more Passengers at Stockholm-Arlanda Airport.

Capacity at Stockholm-Arlanda Airport leads to less Potential congestion at Stockholm-Arlanda Airport. Capacity at Stockholm-Arlanda Airport also leads to more Closing of Bromma Airport.

3.3.4 Matrix

The matrix is the most common technique to compare alternatives, and to show the findings of the impact assessment and evaluation (Therivel & Paridario, 1996). An impact assessment and evaluation matrix is a simple table, in which the environmental aspects and effects prioritized in the scoping process are evaluated for each alternative. The assessment is carried out by regarding important aspects of each impact´s significance, such as scale, irreversibility or likelihood (Therivel & Paridario, 1996).

In this case, the matrix used could be considered a qualitative magnitude matrix, which will be based on the criteria of the expert group and literature review. This method was selected due to the scarcity of details about the alternatives in Swedavia's Draft Masterplan for Arlanda Airport. The absence of details is a limitation for quantitative calculations, because of the high level of uncertainty concerning future plans. Therefore, a qualitative matrix is a good method to approach the environmental impacts of a general plan of terminal expansion.

The matrix will show, for each effect within the different environmental aspects considered, the direction and the significance of the impacts. In the case of direction, the matrix will clarify if there is no impact or if there is, if it is negative or positive. For the significance of the impacts, the matrix will clarify if the impact is meaningful or not, by stating if it is a major or minor impact (Table 3.2). In this process, two main concepts are involved, magnitude and sensitivity. Magnitude refers to the scale of the impact (e.g. size), while sensitivity involves how the particular environment under study could react to a given impact (e.g. residential areas are more sensible to noise than industry areas) (Põder, 2006). Therefore, significance is an interpretation of what is important and desirable from many perspectives (Lawrence, 2007). High magnitude with high sensitivity will mean high significance (Glasson *et al*. 2013).

In this particular exercise, we will use a 5 scale matrix. For each effect, the possibilities will be major negative impact, minor negative impact, no significant impact, minor positive impact and major positive impact. The matrix will present order, direction and significance for all the impacts analysed, and it will also be easy to communicate. A matrix will be done for each of the phases analysed (i.e. construction and operation) and for each alternative. The reason for this is because the environmental changes are different in the two phases. For the alternatives, it is important to be able to compare their various impacts. This will allow for a clear visual comparison of the alternatives in the two phases.

Table 3.2. Scale of impact assessment.

Major positive impact	Exceeds the current environmental standard in a positive direction. Significance is high and the area affected is of low sensitivity.
Minor positive impact	Positive impact that does not constitute a major positive impact. Moderate significance and sensitivity of the area affected.
No impact	No significant impact. Area affected is considered to have low sensitivity.
Minor negative impact	Negative impact that does not constitute a major negative impact. Moderate significance and sensitivity of the area affected.
Major negative impact	Exceeds the current environmental standard in a negative direction. Significance is high and the area affected is of high sensitivity.

For each specific environmental effect described in the matrix. This will support why a given impact is categorized as major or minor, or as positive or negative. We acknowledge that this a subjective process (Glasson *et al*. 2013). Nevertheless, the conclusions will be supported by professional criteria, defined assumptions, literature reviews and map overlay. A component of likelihood will be included in the reflections, based on Engert & Lansdowne (1999) (Table 3.3).

Table 3.3. Terminology for describing probability.

Likelihood	Description
Will	High certainty of the impact to occur.
Likely	Moderate certainty of the impact to occur
May	Possibility of the impact to occur.
Unlikely	Impact is certain to not occur.

3.3.5 Impact, effect, consequence and mitigation

Concepts such as impact, effect and consequence are normally used to describe environmental impacts in EIAs (Figure 3.4). However, such concepts are largely intertwined and it can be difficult to distinguish between them. Thus, these concepts will be more thoroughly explained since they will provide a basis for assessing the environmental impacts in this chapter. The explanations are based on definitions provided by Trafikverket (2017).

Impact - relates to change in the physical, social or economic environment that the proposed expansion of the terminal area is likely to cause, e.g. increased construction noise.

Effect - describes the environmental change that the impact causes, e.g. a loss of important habitats, or people being exposed to noise.

Consequence - is the aftermath of the occurred effects on a certain aspect, e.g. loss of biodiversity, or health related problems as a result of noise disturbances.

An important part of EIAs is to propose measures that can reduce the impacts and, consequently, also the effect and consequences. The overarching concept is called mitigation measures and it is defined in the EC directive 97/11 as "measures envisaged in order to avoid, mitigate and, if possible, remedy significant adverse effects".

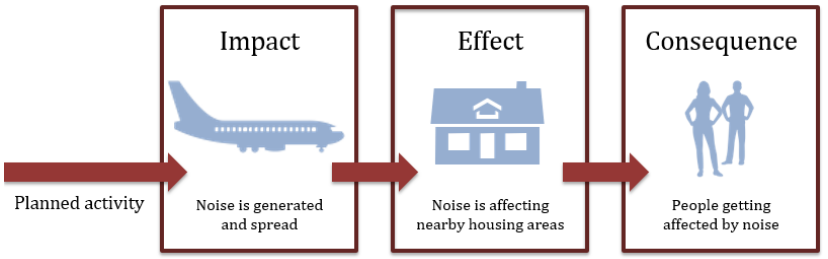

Figure 3.4. Explanation of the relationship between impact, effect and consequence.

3.4 Background

The following section will look at the current conditions at Arlanda Airport, including on-going development programmes

3.4.1 Description of Arlanda Terminals

Arlanda Airport has grown substantially since its inauguration in 1962, and today has four passenger terminals: 2, 3, 4 and 5. International flights operate from terminals 2 and 5, whereas domestic flights operate from terminals 3 and 4. In addition to flight operations, the terminals also house offices, shops and restaurants. The terminal buildings are referred to as belonging to both the landside and airside areas, with the security check normally constituting the boundary. In total, the terminals have an area of 350 000 m^2 (Swedavia, 2011a).

The existing terminal structures have 60 airplane stands (Figure 3.5), of which 54 are attached to piers through jet bridges, and the remaining six are accessed via passageways or bus. Terminal 5 has three separate piers (from south to north, pier B, A and F), whereas the other terminals have one pier each. To get from Terminal 2 to Terminal 5 (pier F) travellers need to walk a distance of 1100 meters (an estimated 20 minutes' walk, all indoors), alternatively take a free shuttle bus or Arlanda Express (Swedavia, 2017a; Swedavia, 2017c).

Between Terminal 4 and 5 is an area open to both passengers and the general public, containing restaurants, shops and other services (including hotels and conference facilities). The area is called SkyCity and no flights operate from there. The high-speed train Arlanda Express has two stations at Arlanda Airport, one beneath Terminal 2, 3 and 4 (Arlanda S) and one beneath Terminal 5 (Arlanda N). The national railway system has its station at SkyCity (Arlanda C) (Swedavia, 2017c).

3.4.1.1 Utvecklingsprogram Arlanda (UPA)

In addition to existing terminal structures, the proposed expansion is based on an on-going development programme, referred to here as Utvecklingsprogram Arlanda (UPA). The programme began in 2014 and is expected to be completed in 2023. During this time, a number of changes will be made to both the airport and the surrounding area, creating a capacity of 35 million passengers per year.

Concerning the terminals, these changes are mainly centred on Terminal 5, which handles around 70 per cent of Arlanda's travellers. The walkway between pier B and A will be reconstructed for better management of the flow of passengers between gates. A central reception of goods for all restaurants and shops will also be developed, as well as a new security check, baggage claim area and handling system. Once completed, Terminal 5 will have one common security check for all passengers, from which they will enter into a new shopping and dining area. Swedavia's aim for the terminal is that it should "feel modern, spacious and inviting" (Swedavia, 2017a).

To meet the prognostic demand for international flight routes, the UPA also includes plans for a new pier at Terminal 5. The prospective name of the new pier is G, and it will be divided into G-North and G-South. By 2022/2023 the new pier will increase the total number of airplane stands to 74 (Swedavia, 2017b). This will enable Arlanda to receive more passengers, as well as larger aircrafts, both of which are expected to increase in the coming

years. Due to newer aircrafts being more silent and fuel efficient than older models, noise and emissions from individual aircrafts are expected to decrease. However, to manage the heavier planes, which mostly belong to the Code F category (a wingspan of 65-80 metres), the runways need to be reinforced. At the time of writing, this has already been carried out on runway 1. Additional measures to streamline the flow of passengers will include a triple jet bridge and improvement to the check-in area (Swedavia, 2017a; Trani & Roa, 2017).

For the new pier and expansion plans to be possible, the existing Ground Vehicles Operation Area will need to be moved, and a new one built in its place. The new area will consist of 13 buildings, for which the layout will be consistent with Swedavia's environmental objectives and certification. Terminal 4 will also see improvements regarding efficiency, and there are plans for expanding Terminal 2 by adding one or two additional piers (Swedavia, 2017a).

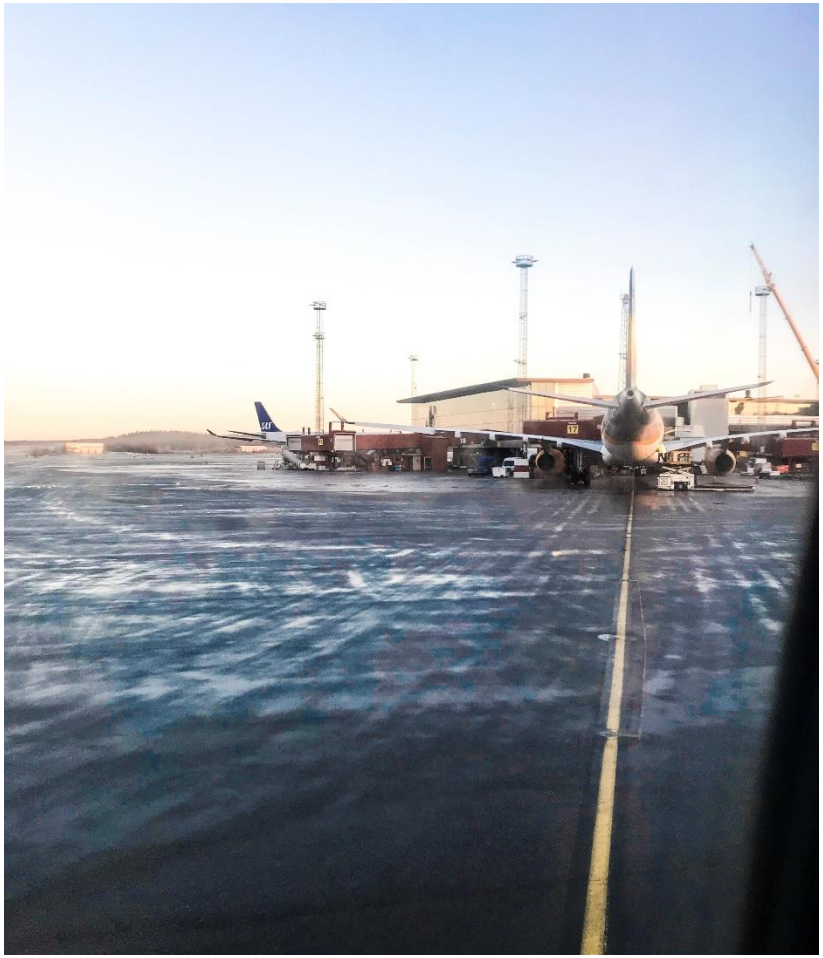

Figure 3.5. Picture of airplane at stand (photo by authors)

3.5 Alternatives

The following section describes the geographical alternatives studied in this chapter. The zero alternative will, further, be investigated and explained.

3.5.1 Delimitations of alternatives

According to 6 ch. 7 § in the Swedish Environmental Code an environmental impact statement should consider feasible alternatives with regard to the geographical scope of the proposed development.

The concept of alternative is defined by the Department of Environmental Affairs and Tourism (2004) in South Africa as a possible course of action, instead of another, that would accommodate the same purpose and need. The aim of investigating alternatives is to find the most effective way of meeting the need and purpose of the proposal, by either reducing or avoiding potential significant environmental impacts or to enhance the environmental benefits of a proposed development.

The consideration of other feasible alternatives is a crucial component in the EIA process. Its importance is emphasized by Glasson *et al*. (2013), the European Commission (2001) and the World Bank (1996). Furthermore, an examination of alternatives ensures that the EIA is not reduced as a justification for a single development proposal but rather that it enables the decision-maker to focus on the optimal course of action.

Based on eight strategic evaluation and decision criteria the Arlanda Draft Masterplan (Swedavia, 2017b) identified five alternative geographical locations for expansion of the terminal area. The alternatives are as follows; central, north, south, east and west.

In the Arlanda Draft Masterplan only two out of the five suggested alternatives were regarded as viable, and that was the central and northern alternative. These alternatives will be investigated further in this chapter. An expansion to the west is dismissed because of the limited space between Runway 1 and highway E4. In addition, it is a peripheral location which will lead to longer taxiways to Runway 2 and 3. The southern alternative is not considered further because of its location close to the E4. An expansion in a southerly direction may also require Cargo City to be relocated. Finally, an expansion to the east will not be plausible because it overlaps with the proposed location of Runway 4. Also, the taxiways to Runway 1 will become longer.

3.5.2 Zero Alterative

According to 6 ch. 12 § in the Environmental Code, an environmental impact statement should contain a description of the environmental conditions and the likely development of the environment if the plan, programme or alteration is not carried out.

This description should act as an additional alternative to the ones proposed, and is sometimes referred to as the "do-nothing" or "no-action" option. In this environmental impact assessment, we will refer to it as the zero alternative. It will be used to describe a situation in which the expansion of Arlanda terminals does not proceed. In accordance with Glasson *et al.* (2013), the zero alternative could be seen as equivalent to a discussion of the need for the project, and if the benefits of carrying it out outweigh its costs.

Arlanda Airport has four passenger terminals that together cover an area of 350 000 m^2 (Swedavia, 2011a). After the completion of UPA, the airport is expected to have a passenger capacity of 35 million passengers per year. This will partly be achieved through the on-going expansion of terminals 2 and 5, including the construction of additional airplane stands, leading to a new total of 74. At present, getting from Terminal 2 to the furthest pier in Terminal 5 will require walking a distance of 1 100 metres (an estimated 20 minutes' walk, all indoors), alternatively taking a free shuttle bus or Arlanda Express (Swedavia, 2017a; Swedavia, 2017c). The high-speed train Arlanda Express has two stations at Arlanda Airport, one beneath Terminal 2, 3 and 4 (Arlanda S) and one beneath Terminal 5 (Arlanda N). The national railway system has its station at SkyCity (Arlanda C) (Swedavia, 2017c).

If the proposed post-UPA expansion does not happen, Arlanda Airport will continue its operations at its current location. If estimations are correct, the airport will see a steady increase in travellers the coming years. Following UPA, Arlanda will be able to handle an additional 10 million yearly passengers to its present capacity. Such an increase would likely demand more efficient public transport to and from the airport. However, there would be no need of introducing new transport means within the terminal buildings. Since passenger capacity at terminals is connected to airplane capacity, Arlanda Airport will not receive more passengers than it can handle. The proposed area for expansion in the north will likely remain in its current state because of restrictions on building within the airport area.

Arlanda will not be able to go beyond a capacity of 35 million passengers without further expansion, and thus, will not reach Swedavia's goal of becoming an international hub with 70 million passengers per year. Due to the maximum capacity of 35 million passengers per year at Arlanda, the expected increase in travellers at Stockholm airports will require Bromma Airport to remain open.

3.5.3 Alternative Central

Alternative Central (Figure 3.6 and 3.7) implies an expansion of the existing terminal buildings. The expansion is, however, limited by the available space in-between the runways. One of the main advantages of expanding the existing terminal structure is its relative location close to Runway 1,2 and 3 as well as all the functions within Airport City. The location also enables close access to existing infrastructure.

An expansion of the existing terminal area can become complicated, time consuming, expensive and can affect the current capacity. However, it is still an interesting alternative because of its close proximity to nodes which gives Arlanda an opportunity to create an intermodal hub for travels. The limited space may nonetheless require an expansion in the north, should the capacity need to increase further in the future. Such an expansion will also mean that Cargo City has to be moved.

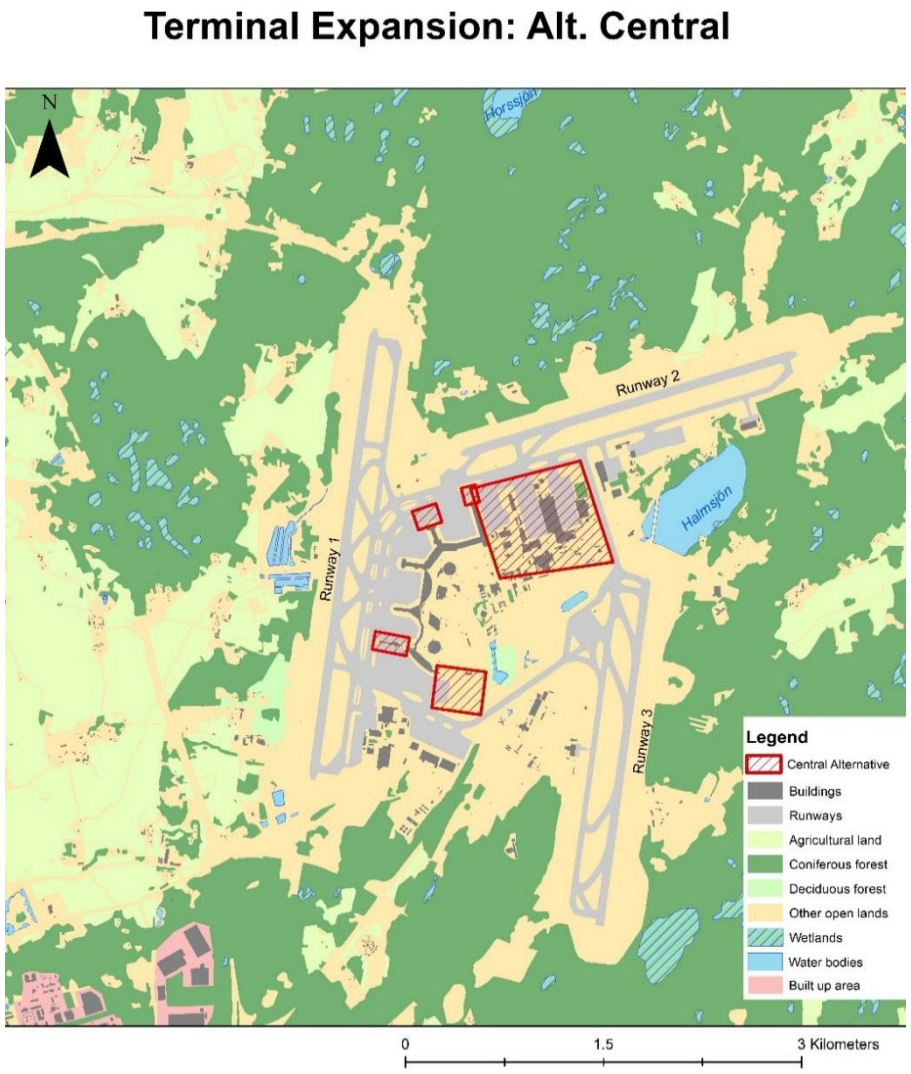

Figure 3.6. Map over expansion areas of Alternative Central. Data collected from Lantmäteriet and created in ArcGIS (Carbonari & Øvereng, 2017).

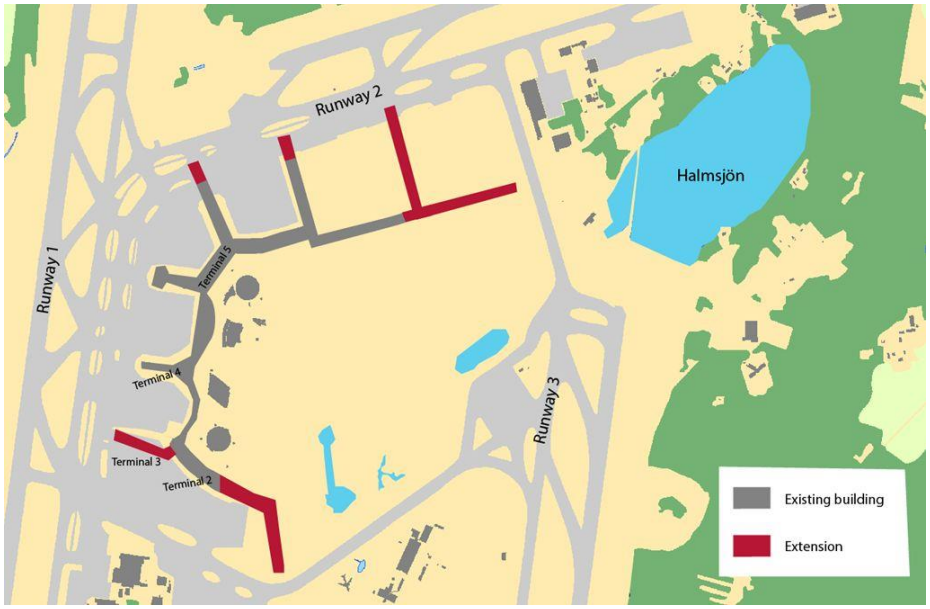

Figure 3.7. Zoomed in view of proposed expansion in Alternative Central, for a capacity of up to 70 million passengers per year (Gordon, 2017).

3.5.4 Alternative North

Alternative North (Figure 3.8) is located north of Runway 2 and in-between Runway 1 and the proposed Runway 4. An expansion in the north will imply the creation of a Terminal 6. The area is limited to the east and west but can be expanded in a northern direction. Since this is an undeveloped site, commonly referred to as greenfield, exploitation is simpler to accomplish. However, it poses some difficulties since it requires new transport infrastructure. This can be done in two ways: either by creating a detached terminal with its own transportation system or by establishing an in-house transportation route that can transport travellers to Terminal 6 from e.g. Terminal 5. Despite these challenges, Alternative North does in fact support a long-term development of more than 70 million yearly passengers. Also, Cargo City and the operations area do not have to move.

The biggest disadvantage is the dividing of the terminal structure. The bisection will create a doubling in functions, lower clarity for passengers both in docking and transfer. It will lead to less flexibility and effectiveness in the operations. Swedavia has the goal of being an intermodal hub, the possibility for this goal to be reached is lowered and creates a challenge in Alternative North. This, together with a limited expansion (or renovation) of the existing terminal structure could, in a transition period, become a big disadvantage for the commercial development in the central airport city. Not until there is established higher capacity and two well-functioning docking directions could there be plans for expanding the airport city in both directions.

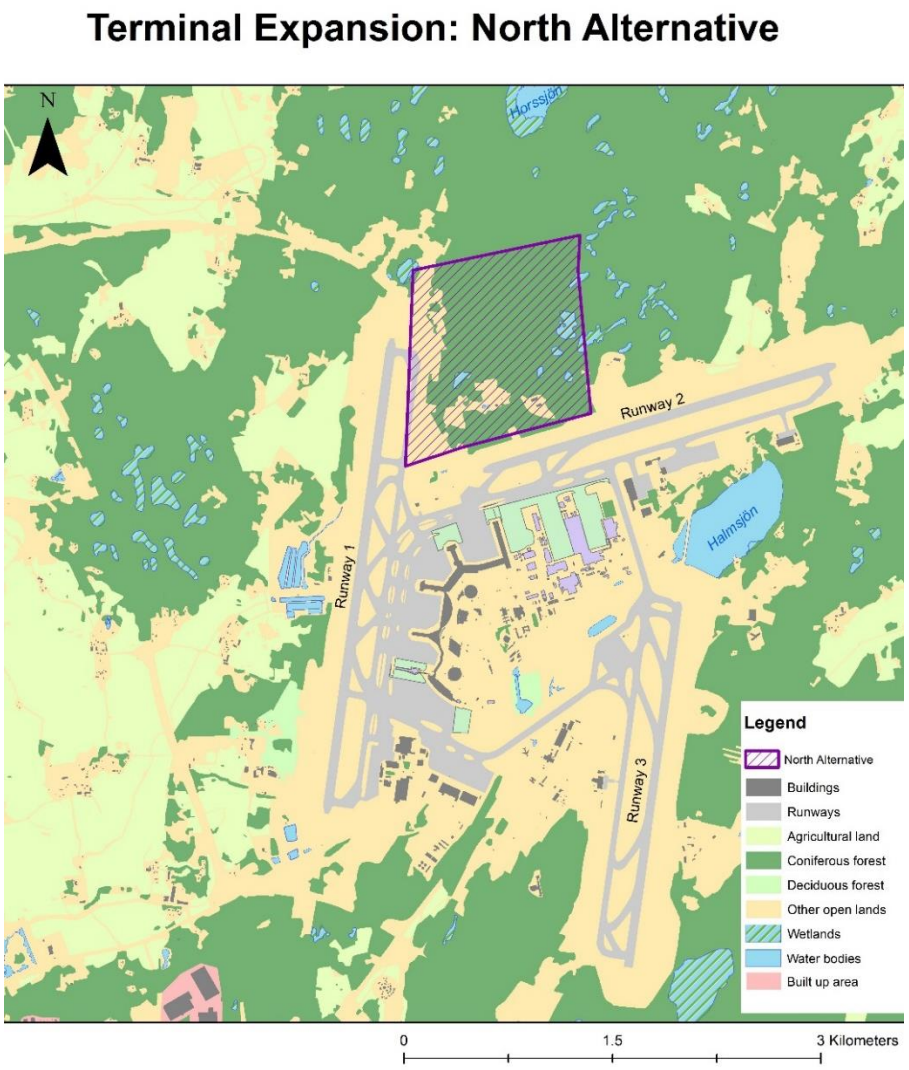

Figure 3.8. Map over Alternative North. Data collected from Lantmäteriet and created in ArcGIS (Carbonari & Øvereng, 2017).

3.5.4.1 Terminal layout of Alternative North

A new terminal structure can be designed in numerous ways (Figure 3.9). In general, there are five main types of terminal configurations: (1) Finger pier (2) Pier Satellite (3) Linear pier (4) Transporter and (5) Midfield pier.

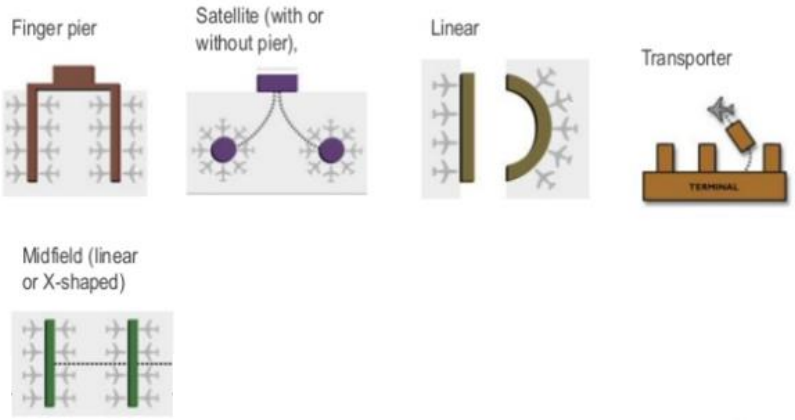

Figure 3.9. Different terminal structure designs.

A Finger Pier is a pier with slots around it where the aircrafts are parked. The benefit of the Finger Pier is its simplicity in design and high aircraft capacity. The disadvantage with Finger Pier design is long distances from the check-in counter to the gate. Furthermore, the Satellite design usually means extension of T-shaped Finger piers, and involves a single building for passengers to pass through. Disadvantages of the satellite configuration is that it often contributes to high costs for operation and maintenance. Moreover, the characteristics of Linear terminal is a linear building with centralized passenger processing. Disadvantages for the Linear design is long walking distances for transfer passengers, and that it is best suited for low activity. The Transporter terminal type means passengers are transported from the building to the parked airplane, which minimizes walking distances and decrease airplane taxiing time. Negative impacts for the Transporter terminal is that it is costly and can cause delays for short haul passengers. Also, the Nordic climate might not be suitable for such a solution. The Midfield pier is usually either linear or X-shaped, and located between two parallel runways separated from the other passenger buildings by taxiways. This type of configuration is considered efficient for reducing delays (Shuchi, 2016).

Which type of terminal that is best suited for Arlanda's expansion depends on traffic patterns, aircraft taxiing around the buildings, walking distance and priorities of stakeholders (Shuchi, 2016). Currently, Arlanda has a combination of finger piers and linear terminal design with 74 stands in total. For the capacity of 70 million passengers 72 additional stands are needed.

For the development of the Alternative North, according to the Masterplan, the new terminal should preferably have parallel taxiways, short distance for taxing to new terminal, good ability to new berthing and expansion of Airport City, close proximity to possible locations and ability for gradual extension of the terminal. In addition, the Draft Masterplan states modern and efficient terminal structures are usually satellites with a T- or star-shape, to be able to combine long piers with centrally located commercial facilities (Swedavia, 2017b). However, the satellite design tends to be very costly to maintain and operate, which is also the case for the Transporter. On the other hand, the linear terminal is mainly used for low activity, which is not the case for Arlanda. Consequently, the Finger pier and/or the Midfield pier seem to be the design options with least disadvantages. The proposed measure is therefore to use either of these designs. To

enable a creation of a flexible design that can change over time, an open plan design and easy removable partition is suggested.

3.6 Environmental baseline, impact assessment and mitigation measures

In this section the environmental impacts identified in during the scoping exercise is explained, assessed and assigned probability. Moreover, mitigation measures are suggested when impacts are considered to be adverse.

3.6.1 Land use

This section will look at land use in relation to the expansion of Arlanda Airport terminals.

3.6.1.1 Environmental baseline

The landscape enclosing Arlanda is diverse, and mixed in a way that is typical for the region of Mälardalen (Länsstyrelsen Stockholm, n.d-a) (Figure 3.10). It is a rural, broken up landscape with forest, farmland, lakes and streams. No larger communities are directly connected to Arlanda or the immediate surroundings. The vicinity of Arlanda is, in the north and south, predominantly forest, while the west and east have both forest and farmland. The eastern side also has more wetland (Ekologigruppen, 2010; Vatten & Samhällsteknik, 2011). Arlanda is set on the Stockholm esker, which greatly affects land use and species in the area (Ekologigruppen, 2010).

Roads in the area are dominated by the passing E4 in the west, and road 273 passing through the airport area from the southwest to the east. There is also local road infrastructure on all sides, and the road entrance for the airport in the south. There are several extraction sites for gravel and rock in the vicinity of Arlanda. In a closed extraction site, adjacent to Arlanda in the northeast, there is a motocross club, Arlanda MC. As Vatten & Samhällsteknik (2011) states, the landscape in the area roughly consists of four components: the airport, the forest, the open landscape and the roads.

Figure 3.10. Birds view of area surrounding Arlanda (photo by authors)

Ecosystem services

Ecosystem services (ESS) provides us with e.g. photosynthesis, soil, food, bioenergy, pollination, clean air and water (Naturvårdsverket, n.d.-a). Since ESS´s source are all forms of living matter ESS are predominantly gained from the semi natural areas enclosing Arlanda.

Connectivity

The vast infrastructure area of Arlanda cuts off dispersal possibilities for a lot of species, making its semi natural surroundings even more important. Different habitats need to be in relative contact to each other. The importance of the issue of connectivity has been stressed in recent years. It can improve biological diversity and thus also affect different ESS in a positive way (Aune *et al*. 2005; Angelstam *et al*. 2011; Naturvårdsverket, 2017a).

Nature value classifications

In 2010, Ekologigruppen released a report on an inventory of nature values, biological diversity and habitats at Arlanda and its vicinity. Areas were listed from 1-4 showing the hierarchy of interest and nature value on different levels on a spatial scale. Lower numbers have a nature value of greater interest: 1) national level; 2) regional/county level; 3) local/municipality level; 4) local/part of municipality level. These classifications apply to some of the baseline land use areas as seen below.

Land use areas

The Masterplan proposes several areas for terminal expansion. The areas that will face the main change in land use, if expansion plans are realised, are all localised to the north of Arlanda. To a large extent this area is coniferous forest, but there are also two extraction sites, one in operation and one closed for extraction, as well as one area of grassland. The areas are consequently categorised into four different parts of land use area in the north of Arlanda. Seen from west to east they are named in the text as: Grassland, Forest, Laggatorp nature reserve and Extraction site (Figure 3.11). There is also a proposal for expansion of the existing terminal structures. This land use area is named Central area in the text.

Grassland

West of the forest area is an area of grass- and scrubland, in the extension of the north end of Runway 1. This type of habitat is found in the start and end of the different runways, due to regular clearing and cutting of vegetation in order to make way for take-offs and landings. The cultivated grassland is considered by Ekologigruppen (2010) to have local nature values on a municipality level. This area also includes Märstaån, a stream that has its source in Lake Horssjön nearby in the north. Märsta stream eventually ends in Lake Mälaren (VISS, 2017). The ground and soil conditions in the area are affected by its relatively low topographic location. Some wetland remains from a former lake and soils are mostly clay, peat and till with a soil depth reaching from 0-10 metres above the bedrock (SGU, 2017a, 2017c). The area has a nature value of 3, and is of interest on local/municipality level, as stated by Ekologigruppen (2010).

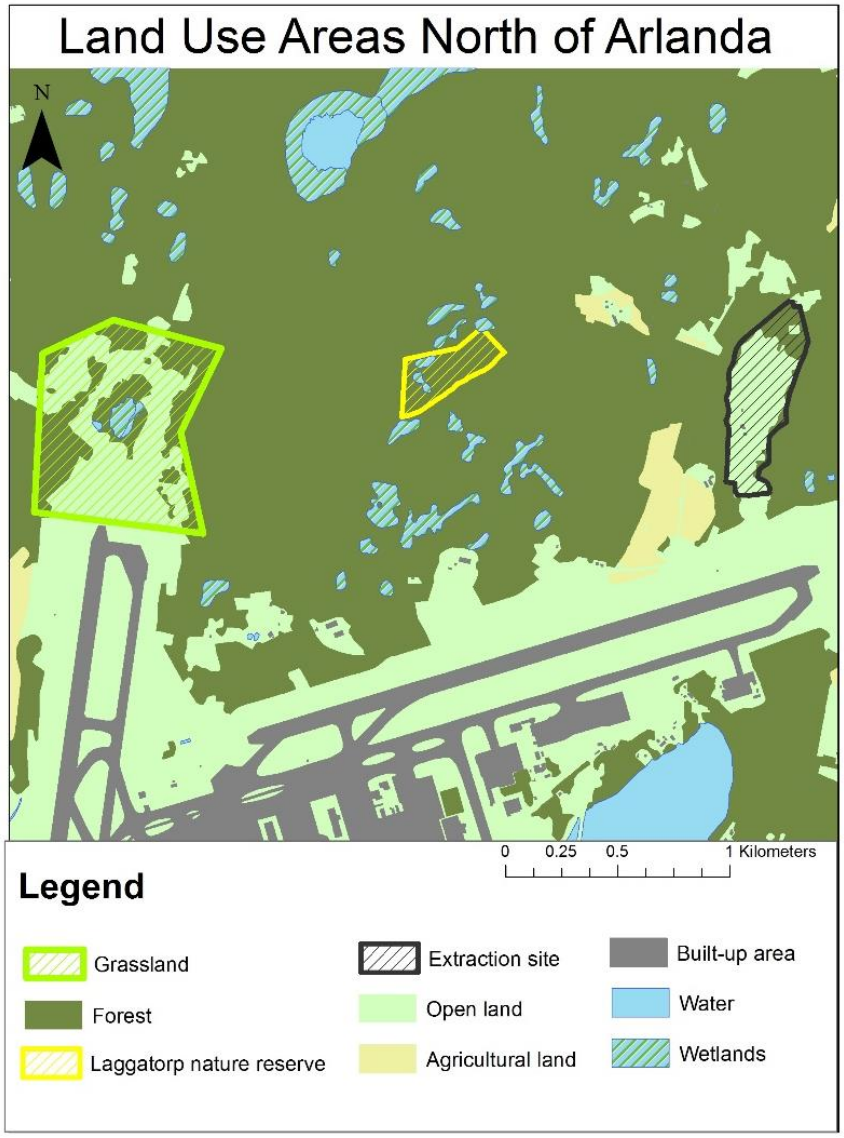

Figure 3.11. Map of land use areas north of Arlanda. Data collected from Lantmäteriet (Carbonari & Werner, 2017).

Forest

The forestry managed coniferous area in the north (Vatten & Samhällsteknik, 2011; Länsstyrelsen Stockholm, n.d.-b) reaches topographically higher than its surroundings. The forest is mainly standing on till and crystalline bedrock with a soil depth of 0-3 metres or, occasionally, 3-5 metres (SGU, 2017a, 2017b). This forest occupies the majority of the area north of Arlanda. Hence, it is spatially larger than the three other areas in this land use baseline survey. The area is not listed as an area of specific nature value by Ekologigruppen (2010). Notwithstanding, in the northeast the area of Forest surrounds the land use area of Laggatorp nature reserve, valued 2, (described below). Forest is also, westward, adjacent to the land use area of Grassland, valued 3.

Laggatorp nature reserve

The coniferous forest in the north of Arlanda also includes the 8,2-hectare nature reserve of Laggatorp. The reserve has a long continuity with no traces of forestry. Trees are mainly pine (*Pinus sylvestris*), growing partly on plain crystalline bedrock of granite and gneiss (SGU, 2017a, 2017b). Many of these trees has reached an age of approximately 250 years. Laggatorp is therefore an important habitat for several species, both flora and fauna, bound to habitats with long continuity. There are till and peat in the shallow depressions (SGU, 2017a) with lichens and mosses covering the ground (Länsstyrelsen Stockholm, n.d.-b). Laggatorp nature reserve is a compensatory object, in accordance with Swedish Environmental Code ch. 7 § 7, due to the withdraw of the protection of the Benstocken nature reserve in the 1980s, which now is part of the airport operation area. The surroundings of Laggatorp are managed through forestry (Länsstyrelsen, n.d.-b;

Naturvårdsverket, n.d.-b). The area has a nature value of 2, and is of interest on regional/county level, as stated by Ekologigruppen (2010).

Extraction site

The closed, and more eastern, extraction site is a habitat of significant regional value, due to its exposed, sandy areas. It is also the site of an operational motocross track managed by Arlanda MC, and therefore holds recreational value. The habitat is maintained by disturbance of the ground caused by the vehicles (Lönell & Ljungberg, 2006; Ekologigruppen, 2010). This makes it a quite rare, and therefore important, type of habitat for both flora and fauna. Trees are predominantly younger pine (*Pinus sylvestris*) (Ekologigruppen, 2010). The sand and gravel in the ground are part of the Stockholm esker, which originates from Quaternary Ice Age deposits with a soil depth of 3-10 metres, in some parts 10-20 metres, on the bedrock (SGU, 2017a, 2017b, 2017c). The deposits are classified as a finite natural resource (Naturvårdsverket, n.d.-c). The area has a nature value of 2, and is of interest on regional/county level, as stated by Ekologigruppen (2010).

Central area

This area is predominantly hard surfaces and infrastructure, utilised for airport purposes such as terminal buildings, roads and so forth. There are patches of airside areas with cut grass that, according to Karelis *et al*. (2017, personal communication, November 30), include a few rare plant species. Ekologigruppen (2010) states that in the central parts of the airport there are edge areas and disturbed patches of land that can be quite rich in certain plant species, but that rare species and species in need of protection are not common in these habitats. The area is not listed as an area of specific nature value by Ekologigruppen (2010).

Recreation

Some of the areas for terminal expansion, as seen under Alternatives, have a recreational function to some extent. But they are not mentioned as valuable recreational areas by the County board and the Regional planning office. Seen in a local perspective, the area north of Arlanda is considered to be of significant recreational interest according the municipality of Sigtuna (Vatten & Samhällsteknik, 2011). The comprehensive plan for Sigtuna (2014), states that the more valuable recreational area is further north and is therefore not adjacent to Arlanda ground operational area in 2014. Notwithstanding, there are recreational values mainly concerning the land use areas of Laggatorp nature reserve and Forest. In the eastern part there is also a motocross track managed by Arlanda MC. The areas north of Arlanda is, depending on season, used for hunting (Vatten & Samhällsteknik, 2011).

3.6.1.2 Zero Alternative – impacts

Impacts during construction phase

The impacts include the implementation of the UPA, and concerns land use area Central. The effect will be a change in land use from one form of airport infrastructure to another. Areas that today consist of buildings and roads etc., or have done in the past, will instead house new piers and processors. The consequences will be limited, seen from a land use and landscape perspective. This

is true provided that the pier and processor does not exceed the boundaries of existing buildings and other constructions, regarding e.g. height and foundations.

Impacts during operation phase

No further change in land use other than those in the construction phase. Depending on the architecture, there are possible visual effects that can affect the landscape.

Conclusion

In terms of change in land use there will be no significant impact from the UPA, neither in the construction nor the operation phase. What will happen in the four different land use areas in the north (Grassland, Forest, Laggatorp nature reserve and Extraction site) will therefore not depend on effects of the UPA. Notwithstanding, some of these areas will go through a change in some way, depending on the way they are managed. This assessment, regarding the Zero Alternative, looks at possible impacts over a period of 50 years. Grassland: No effects as long as Runway 1 is used as today and this area is managed the same way. Forest: As long as it is still managed by forestry it will have the same vegetation cycle as today. Laggatorp nature reserve: More or less the same as today. Mainly depending on the implications of the nature reserve management plan. Extraction site: The habitat will continue to exist as long as the management is the same, e.g. a motocross track, or a similar way of disturbing the ground. The younger trees in the area will grow taller which will have a greater shade effect of the ground. Thus affecting certain insect and plant species negatively (Lönell & Ljungberg, 2006; Ekologigruppen, 2010).

3.6.1.3 Alternative Central – impacts

Impacts during construction phase

The impacts go somewhat beyond the implementation of the UPA, and still concerns only the land use area Central. Effects and consequences as in the zero-alternative.

Impacts during operation phase

No further change in land use other than those of the construction phase. Depending on the architecture, there are possible visual effects that can affect the landscape.

Conclusion

In terms of change in land use there will be no significant impact, neither in the construction phase nor the operation phase.

3.6.1.4 Alternative North – impacts

Impacts during construction phase

The impacts include the implementation of the UPA from the Zero Alternative. Beyond this, there will be an exploitation of new land in the northwest. This will include a new terminal with processor and possible new piers. In terms of change in land use and landscape, the impacts will be extensive and on a large scale. The western part of land use area Forest will face deforestation and relatively large quantities of solid bedrock will possibly have to be blasted away, in order to reach runway level altitude. No forestry will be possible in the exploited area. The consequences are

disturbance and reduction of the coniferous forest area as a recreational area and habitat.

Due to the fact that the proposed location of this exploitation is only approximate, there are two likely scenarios for Laggatorp nature reserve: either the reserve will be reduced in area, or it will be intact, but adjacent to the new terminal area. Both scenarios will strongly affect the experience and purpose of the reserve. Existing ecosystem services (ESS) in the exploited area will not be possible to maintain, if all vegetation and soil is removed and replaced by hard surfaces. This will possibly also weaken the ESS of the areas adjacent to the exploited area, due to e.g. decrease in connectivity and dispersal of species. There will also be visual and audible effects. Disturbance will increase in land use area Grassland, since it is adjacent westward of the construction area. The buffer zone that today exists between the north part of Arlanda operational area, and the more valuable recreational areas in the north, as described in the comprehensive plan for Sigtuna 2014, will be narrow or non-existent.

Impacts during operation phase

The impacts, effects and consequences are very much the same as those in the construction phase. The main impact for the area concerns the initial change in land use. Thus, affecting recreation, vegetation, habitat, biological diversity and ESS. One difference is that in the operation phase, there is no impact on the vegetation and the function as a habitat. This is explained by the presumed physical removal of these parameters during the construction phase. Beyond this there will be visual and audible impact from buildings. The possible verge in the bedrock, caused during the construction phase, will form an edge separating this new terminal area from the land use area Forest. The visual impact will lead to landscape change and effects and consequences on recreational experiences for adjacent areas, e.g. for visitors to Laggatorp nature reserve. Detrimental ecological effects and consequences of a connectivity decrease will perhaps be noticeable only in the long run.

Conclusion

The effects and consequences will be major negative, both in the construction phase and the operation phase. This concerns the area of exploitation and the areas of Forest and Laggatorp nature reserve. If the construction and/or operation area overlaps with the area of Laggatorp nature reserve, a reasonable compensation area has to be located.

Mitigation

The most important mitigation measure is probably to set a sufficient distance between the areas of construction/operation and Laggatorp nature reserve. This could be achieved by decreasing the area of the terminal expansion, or to extend the area northward and decrease it eastward. The latter will also lessen the amount of bedrock that has to be removed, since the eastern part of the proposed expansion area is higher and contains more bedrock above the existing runway level. It will also reduce the height of a steep verge, which may be a result from blasting. An assessment of existing ESS in the semi natural areas of Arlanda can serve as the basis for decisions on mitigation of adverse effects on ESS.

3.6.2 Air quality

In this section we will look at particulate matter, ozone, nitrogen dioxide as well as greenhouse gas emissions. Furthermore, transportation within the airport, electricity and heating will be discussed in brief.

3.6.2.1 Environmental baseline

The quality of the air is a primary objective of the environmental policies around the world due to the direct connection with public health (Neidell, 2004). Nevertheless, what kind of air pollution should be included, and what should be the limit, is still a matter of debate in science and public policy (Stieb *et. al*, 2012).

Despite the on-going debate, interpretations of air quality exist in legislation around the world. The Air Quality Ordinance of Sweden (2010:477), following the EU directives 2004/107/EC and the 2008/50/EC, determines density thresholds for 11 substances that are considered hazardous once they are in the air. The substances to which attention will be paid are the ones in the Air Quality World Health Organization Guidelines of 2005. Therefore, the present study will be considering particulate matter (PM), Ozone (O_3) and Nitrogen Dioxide (NO_2). The sources of these pollutants can be several, from construction operations to combustion and waste management (WHO, 2005). Due to the resolution of the information, it is difficult to distinguish air pollution in the terminal area from pollution in the airport's immediate surroundings. The sources of information for this analysis is the environmental report for Arlanda Airport from 2016 and the project UrbanSIS.

Particulate matter

In environmental legislation and technical analysis, the particulate matter is usually divided in two: particles with a diameter of 10 micrometre or less (PM10) and particles with a diameter of 2.5 micrometre or less (PM2.5). In the case of Arlanda Airport, the level of PM10 has been measured and reported, while measuring of PM2.5 is still in process (Swedavia, 2017e). The level of PM10 registered as the monthly average was 13.1 $\mu g/m^3$. The highest monthly mean was in June with 21.5 $\mu g/m^3$ and the lowest monthly mean was December with 5 $\mu g/m^3$ (Swedavia, 2017e). This is consistent with other historical information. According to UrbanSIS (2017), the yearly average from 2006 to 2014 has always been below 20 $\mu g/m^3$. Regarding the PM2.5 the behaviour is similar to the bigger particles, with the level, from 2006 to 2014, always being lower than 20 $\mu g/m^3$ (UrbanSIS, 2017).

Ozone (O_3)

High levels of ozone (O_3) in the troposphere can lead to health problems if the substance is inhaled. This substance can also have a negative impact on vegetation. The level of ozone at Arlanda is highly dependent on emissions in other areas. Nevertheless, ozone in the ground level of the atmosphere is still a criterion for measuring air quality at the airport and its surroundings. At Arlanda Airport, the level of O_3 in 2016 was 58 $\mu g/m^3$, which is slightly higher than the value for 2015 (Swedavia, 2017e). Concerning the monthly average, the higher values occurred in July, while the lower values occurred in January (Swedavia, 2017e). According to UrbanSIS (2017), the yearly average from 2006 to 2014 has fluctuated from 65 to 50 $\mu g/m^3$.

Nitrogen dioxide (NO_2)

This compound (NO_2) is used as an indicator of general nitrogen oxides (NO_X), which are highly reactive, and usually originates from the combustion of fuel. Nitrogen oxides have direct impact on the respiratory system, can cause acid rain, contribute to low visibility and to nutrient pollution. In 2016, the yearly average of nitrogen dioxide was 7.9 µg/m^3 (Swedavia, 2017e). Higher values are usually registered in winter, while lower values are register in summer. In January of 2016, the monthly average was slightly below 10 µg/m^3, while in July it was slightly above 5 (Swedavia, 2017e). The measurements performed by Swedavia are consistent with other data sources. According to UrbanSIS (2017e), the yearly average from 2006 to 2014 was always below 12 µg/m^3. The seasonal behaviour is also persistent in the UrbanSIS (2017) database.

GHG emissions

Carbon neutrality is an important objective for Sweden as a nation. The Swedish Parliament has decided on a climate policy framework for the country to reach zero net emissions of greenhouse gases by 2045 at the latest (Naturvårdsverket, 2017b). For Swedavia, zero GHG emissions in its own operations is one of the company's four sustainability targets, and should be accomplished by 2020 (Swedavia, 2017e). For the purposes of this chapter we will focus only on direct CO_2 emissions. The sources that will be considered are energy consumption and transport within the airport. Land use alterations will also be explored, to take into account potential changes in future construction phases.

Transport within the Airport

Within Arlanda Airport there is transportation of materials and people. This implies vehicles and, in turn, combustion engines. In 2016, the diesel used was mixed at a level of 50 per cent with renewable raw materials. In terms of gas engines, the fuel used at Arlanda was 70 per cent biogas and 30 per cent natural gas (Swedavia, 2017e). The carbon dioxide emissions were calculated based on the carbon content of each type of fuel, whereas other GHG, such as NO_X, were calculated using Trafikverket Forecast Emission Factors. From these sources, the CO_2 emissions in 2016 were 2 632 tons (Swedavia, 2017e).

Energy: Electricity and heating

The emissions linked to this use of energy depend on the type of technology and resources used to produce it. The energy at Arlanda comes mostly from purchased heating and electricity, but is supported by the use of aquifers. There are some oil boilers for backup purposes, and for certain private businesses. Arlanda Airport's energy use in 2016 was around 130 000 MWh, of which Swedavia uses approximately 45 per cent. The electricity consumption is decreasing due to improvements in energy efficiency. For heating and electricity, there are no associated carbon dioxide emissions. Since 2013, Swedavia has been purchasing heat produced from biofuel, which is carbon neutral, and electricity that comes from renewable energy sources. Therefore, the only emissions from energy are the ones from the external oil boilers. Those emissions were 290 tons of CO_2 in 2016 (Swedavia, 2017e).

3.6.2.2 Zero Alternative - impacts

Impacts during construction phase - Particulate matter

All construction of infrastructure generates particulate matter. The diesel engines of heavy machinery, usually called Non-Road Mobile Machinery (NRMN) generate PM2.5. The construction related dust, produced by construction activities such as demolition or grinding of soil, is a source of PM10. However, out of all the sources, the most significant one is the process of earthmoving (Muleski *et al.,* 2005).

The scale of the construction and the site in which it will be carried out are the most important factors to consider. According to existing plans, the expansion of the terminal is relatively small in size and will take place in already built areas. These conditions mean that the use of NRMN will be limited, nor will earthmoving operations be necessary. It is therefore assumed that the construction phase of the Zero Alternative will have a small impact in terms of magnitude. Regarding sensitivity, there is a quality environmental goal of 40 $\mu g/m^3$ (monthly average) and the quality environmental target is 15 $\mu g/m^3$ (monthly average). The current values of 13.1 $\mu g/m^3$ are therefore below the environmental thresholds. Based on the actual levels, and the thresholds for the area, we conclude that the sensitivity is low. Following this assessment, it is concluded that the construction phase of the Zero Alternative will have a minor negative impact.

Impacts during operation phase - Particulate matter

The operation phase of the Zero Alternative could cause particulate matter to be generated, mainly through the use of oil boilers, or the gas engines that can be used as a backup to heat up the terminals. That said, this equipment is currently being replaced at Arlanda Airport. Based on the assumption that the replacement is successful, there will not be any particulate matter generated in the operation phase. The sensitivity regarding particulate matter is low, due to the fact that the current levels are below the environmental standards and targets. With no perceivable impact, as well as low sensitivity, we conclude that there will not be any significant impact.

Conclusions - Particulate matter

The construction phase of the Zero Alternative will have a minor negative impact. In the operation phase there will be no significant impact.

Mitigation - Particulate matter

Limiting the on-site speed of the vehicles can reduce the generation of particulate matter. Other mitigation measures to be considered could be to use a dust suppressant to unpaved areas, and prohibit activities during high winds.

Impacts during construction phase - Ozone (O_3) and Nitrogen dioxide (NO_2)

Other air pollutants, like ozone and nitrogen dioxide, could be generated in the construction process from the combustion of diesel engines common in NRMN. Construction equipment is a major source of air pollutant emissions (Heidari & Marr, 2015). Therefore, an important aspect to consider is the total machinery used, as well as how long it is used for.

Based on the previously mentioned, and due to the small scale of the construction for the Zero Alternative, the magnitude of the emissions of NO_2 and related O_3 will probably be minor. Current levels of these two substances are below the environmental thresholds. In the case of nitrogen dioxide, the environmental quality standard is 40 $\mu g/m^3$ while the environmental quality target is 15 $\mu g/m^3$. The current levels are below 8 $\mu g/m^3$ and therefore sensitivity is low. In the case of ozone, the situation is different. The environmental quality standard is 120 $\mu g/m^3$ while the environmental quality target is 50. The current level is 58. This means that sensitivity could be considered to be medium in the case of ozone. In spite of that, the ozone is probably influenced by combustion happening in other areas away from the terminal, which makes it highly difficult to link the emissions from a low scale construction to higher levels of ozone. Nevertheless, the magnitude is very low, and the combined sensitivity is medium, therefore the significance of the impact is low.

Impacts during operation phase - Ozone (O_3) and Nitrogen dioxide (NO_2)

As with particulate matter, the only potential source of ozone or nitrogen dioxide within terminals' operations is the combustion of fuels. It is therefore expected that no emissions of these substances will come from the operation phase of the Zero Alternative. Due to current levels being below the environmental thresholds, the sensitivity for nitrogen dioxide is low. Current levels of ozone, on the other hand, is only below the target threshold, causing sensitivity to be regarded as medium. The combination of no magnitude with medium-low sensitivity means no significance for the impact.

Conclusions - Ozone (O_3) and Nitrogen dioxide (NO_2)

In the construction phase of the Zero Alternative, the magnitude of the impact very low. We therefore conclude that there may not be any significant impact. Likewise, in the operation phase it is also concluded that there will not be any significant impact.

Mitigation - Ozone (O_3) and Nitrogen dioxide (NO_2)

Mitigation is not needed.

Impacts during construction phase - GHG emissions

For GHG emissions, only direct CO_2 emissions are considered. Since the Zero Alternative is a minor expansion of the terminal already in place, no emissions are expected from change in land use. In addition, the sources of heating and electricity at Arlanda are certified as clean. The only expected emissions will be generated from the construction machinery and its diesel engines. However, the scale of the construction is small enough to be considered a low magnitude impact. That said, the sensitivity regarding emissions could be very high. In particular, because of Swedavia's commitment to reach zero emissions by 2020. Any carbon emission would have to be compensated for. Consequently, the direction of the impact will be negative, while the significance will be low.

Impacts during operation phase - GHG emissions

The only potential source of direct CO_2 emissions in the operation phase of the Zero Alternative is electricity and heating. But the external and back-up oil boilers are being replaced to meet the goal of zero emissions by 2020. Therefore, no direct CO_2 emissions are expected from the operation phase, and the

magnitude of the impact is zero. However, the sensitivity could be very high, due to the commitment of Swedavia to reach zero emissions by 2020. Nonetheless, due to the absence of magnitude, this high sensitivity still generates a low significance.

Conclusions - GHG emissions

In the construction phase there may be a minor negative impact, while in the operation phase there may not be any significant impact regarding GHG emissions.

Mitigation - GHG emissions

Idle reduction equipment can be introduced, to use less diesel in operations. Engine preventive maintenance and equipment operator training are also viable options. In addition, there are fuel strategies such as use of biodiesel or ultra-low sulphur diesel. Other mitigation measures concerning equipment are engine repower or upgrades and electrification (EPA, 2007). However, if diesel is used there will always be some emissions, which would necessitate compensation through carbon certified credits.

3.6.2.3 Alternative Central – impacts

Impacts during construction phase - Particulate matter

Alternative Central would require an expansion on a large scale, to meet the capacity of 70 million passengers per year. As of yet there is no detailed plan, but under the assumed polygon, the area affected could be around 0.84 Km^2. However, most of the (99 per cent) proposed area is already developed. Under these circumstances we can expect more heavy machinery, but a medium level of earthmoving processes. The magnitude of the generation of particulate matter will therefore not be high. As previously mentioned, the sensitivity is low, due to current levels of particulate matter being below two environmental thresholds. Nonetheless, some negative impact will occur, due to the scale of the construction process. Hence, the direction of impacts will be negative but the significance will be low.

Impacts during operation phase - Particulate matter

Equipment like oil boilers is being replaced at Arlanda Airport in on-going plans. If the expansion in Alternative Central is constructed under the same parameters, there will be no particulate matter generated in the operation phase. The sensitivity regarding particulate matter is low, due to the fact that the current levels are below the environmental standards and targets. For the operation phase there is no perceivable impact and low sensitivity.

Conclusions - Particulate matter

For the construction phase of Alternative Central we can conclude that a minor negative impact may occur. For the operation phase we conclude that there will not be any significant impact.

Mitigation - Particulate matter

Limiting the on-site speed of the vehicles can reduce the generation of particulate matter. Other important mitigation measures to be considered could be dust suppressant to unpaved areas, and prohibit activities during high winds.

Impacts during construction phase - Ozone (O_3) and Nitrogen dioxide (NO_2)

Due to the large scale construction required for Alternative Central, the magnitude of the emissions of NO_2 and related O_3 is medium. The sensitivity in the case of nitrogen dioxide is low, because current levels are below the two environmental thresholds (environmental quality and environmental target). In the case of ozone, the sensitivity is medium, because the current levels are only below the environmental target. Taking into account the magnitude and sensitivity, the significance of the impact is medium. While the direction is negative, it is not likely to be a major negative impact.

Impacts during operation phase - Ozone (O_3) and Nitrogen dioxide (NO_2)

Based on current technical transformations for not using fuel, zero magnitude is expected during the operation phase. Due to current levels of nitrogen dioxide emissions being below the environmental thresholds, the sensitivity is considered to be low. Regarding ozone, due to current levels being below one environmental threshold, the sensitivity is considered to be medium. The combination of no magnitude with medium-low sensitivity means no significance for the impact.

Conclusions - Ozone (O_3) and Nitrogen dioxide (NO_2)

In the construction phase for Alternative Central, we conclude that there may be a minor negative impact. For the operation phase we conclude that there will not be any significant impact.

Mitigation - Ozone (O_3) and Nitrogen dioxide (NO_2)

The same mitigation measures for GHG emissions as in the Zero Alternative are proposed for this.

Impacts during construction phase - GHG emissions

For GHG emissions we only consider direct CO_2 emissions. In the construction phase, the diesel engines of the construction machinery, temporal electricity generation based on fossil fuels and land clearing could lead to direct CO_2 emissions. In Alternative Central, the majority of the proposed area for expansion is already built on, but a small portion of coniferous forest might be affected (0.009 Km^2), leading to some emissions related to land change. There will be emissions generated from the construction machinery and its diesel engines, due to the scale of construction. Due to the sources used at Arlanda for heating and electricity, no GHG emissions are expected. However, the sensitivity regarding emissions could be very high, because of Swedavia's commitment to reach zero emissions by 2020. Consequently, the direction of the impact will be negative and the significance of the impact will be medium.

Impacts during operation phase - GHG emissions

The only potential source of direct CO_2 emissions in the operation phase for Alternative Central is electricity and heating. But the external and back-up oil boilers are being replaced to meet the goal of zero emissions by 2020. Therefore, no direct CO_2 emissions coming from the operation phase are expected, and the magnitude of the impact is zero. However, the sensitivity regarding emissions could be very high, due to the commitment of Swedavia to reach zero emissions by 2020. Any carbon emission

would have to be compensated for. Nonetheless, due to the absence of magnitude, this high sensitivity still generates a low significance.

Conclusions - GHG emissions

For the construction phase in Alternative Central, there may be a minor negative impact. Concerning the operation phase there may not be any significant impact regarding GHG emissions.

Mitigation - GHG emissions

The same mitigation measures for GHG emissions as in the Zero Alternative are proposed for this.

3.6.2.4 Alternative North – impacts

Impacts during construction phase - Particulate matter

The scale of Alternative North could lead to a significant increase in levels of particulate matter. The proposed area for the alternative is 1.8 km^2 of land, mainly covered by vegetation. This is based on Swedavia´s Masterplan polygon. Even though the exact boundaries of the area could change with more detailed plans, the important factor to consider here is that a new terminal in the north would require land clearing. Since earthmoving operations is the principal source of particulate matter, Alternative North could generate very high levels of it. Also, because it will not be built in an already developed area, this alternative would most likely require more heavy machinery. This increased use of construction equipment could also lead to high levels of particulate matter. Based on these two facts, we can expect a high magnitude impact.

The sensitivity in this area is the same as in other areas of the airport. The current level, below the two environmental thresholds (environmental quality and environmental target), supports the definition of a low sensitive area. Nevertheless, due to a potentially high magnitude impact, we assume it is safer to conclude a high significance for the negative impact.

Impacts during operation phase - Particulate matter

We expect no particulate matter during this phase and, as such, the magnitude is zero. The sensitivity regarding particulate matter is low, due to the fact that the current levels are below the environmental standards and targets. Hence, there is no perceivable impact and low sensitivity. We conclude that there will not be any significant impact.

Conclusions - Particulate matter

Regarding particulate matter during the construction phase of Alternative North, we conclude that a major negative impact may happen. For the operation phase, there is no significant impact.

Mitigation - Particulate matter

We propose the same mitigation measures for particulate matter as in Alternative Central.

Impacts during construction phase - Ozone (O_3) and Nitrogen dioxide (NO_2)

Because Alternative North is a large scale project, construction machinery could be used intensively leading to high levels of

emissions. Therefore, the magnitude of the impact could be medium. The sensitivity for nitrogen dioxide is low, due to current levels being below environmental thresholds. In the case of ozone, the sensitivity is medium because the current levels are below the environmental standard, but not below the environmental target. Nevertheless, the ozone measured at the airport is also caused by combustion processes in other areas. It is therefore not safe to assume that combustion at the airport will lead to higher ozone rates at the airport. Because the magnitude is medium-high and the sensitivity is low-medium, we conclude that there will be no significant impact, even though the direction is clearly negative.

Impacts during operation phase - Ozone (O_3) and Nitrogen dioxide (NO_2)

As with particulate matter, the only potential source of ozone or nitrogen dioxide within the terminals' operations is combustion of fuels. Because of the on-going transformation of these processes, no emissions of these substances are expected from the operation phase of Alternative North. Due to current levels being below the environmental thresholds, the sensitivity for nitrogen dioxide is low. Current levels of ozone, on the other hand, are below the target environmental thresholds, causing sensitivity to be regarded as medium. The combination of no magnitude with medium-low sensitivity means no significance for the impact.

Conclusions - Ozone (O_3) and Nitrogen dioxide (NO_2)

Regarding other pollutants in the construction phase there may be a minor negative impact in Alternative North. For this environmental effect we conclude that there will not be any noticeable impact. In operation phase there will not be any noticeable impact.

Mitigation - Ozone (O_3) and Nitrogen dioxide (NO_2)

The same mitigation measures for GHG emissions as in the Zero Alternative are proposed for this.

Impacts during construction phase - GHG emissions

Alternative North is a large scale project, and construction machinery could be used intensively leading to high levels of emissions from diesel engines. Therefore, the magnitude of the impact could be considered to be medium. At this stage we do not expect GHG emissions coming from electricity use or heating, based on Swedavia's current policies regarding Arlanda´s operations. However, the emissions from land use changes is an interesting point concerning Alternative North. Based on the polygon presented, the proposed area includes wetlands, which are carbon sinks. In addition, there is 1.4 km^2 of coniferous forest, which can have 50 000 tons of CO_2 in aboveground biomass. Consequently, there is a risk for high levels of direct CO_2 emissions. The sensitivity regarding emissions could be very high, due to the Swedavia's commitment to reach zero emissions by 2020. Any carbon emission would have to be compensated for. The direction of the impact will therefore be negative and the significance will be high.

Impacts during operation phase - GHG emissions

Under the assumption that rightful technical improvements are currently being made, we are not expecting any direct CO_2 emissions from the operation phase in Alternative North. This is also based on the assumption that the new terminal will be built under the same parameters as the on-going plans. Hence, we expect an impact magnitude of zero. However, the sensitivity

regarding emissions could be very high, because of Swedavia's commitment of reaching zero emissions by 2020. Nonetheless, due to the absence of magnitude, this high sensitivity still generates a low significance.

Conclusions - GHG emissions

In the construction phase there may be a major negative impact. For the operation phase there may not be any significant impact regarding GHG emissions in Alternative North.

Mitigation - GHG emissions

The same mitigation measures for GHG emissions as in the Zero Alternative are proposed for this.

3.6.3 Hydrology and water use

This section outlines the baseline for hydrology and water use and further discusses the environmental impacts of an expansion of Arlanda Airport terminals.

3.6.3.1 Environmental baseline

The project area is in its entirety located within the catchment area of Märsta stream, which is the final surface water recipient in the area (Figure 3.12). The emissions from the airport to Märsta stream have decreased since the 1990s. Today, the stream has a good ecological status (Sigtuna Kommun, 2002). The surrounding lakes, Horssjön and Halmsjön, have the environmental status of moderate in their levels of phosphorus, nitrogen and heavy metals. However, because of elevated levels of PFOS (perfluorooctane sulphonate) Swedavia has decided to stop all fishing activities in Halmsjön until further notice. The groundwater in the area is abundant, but the chemical status of this groundwater does not meet the national standards (VISS, 2017).

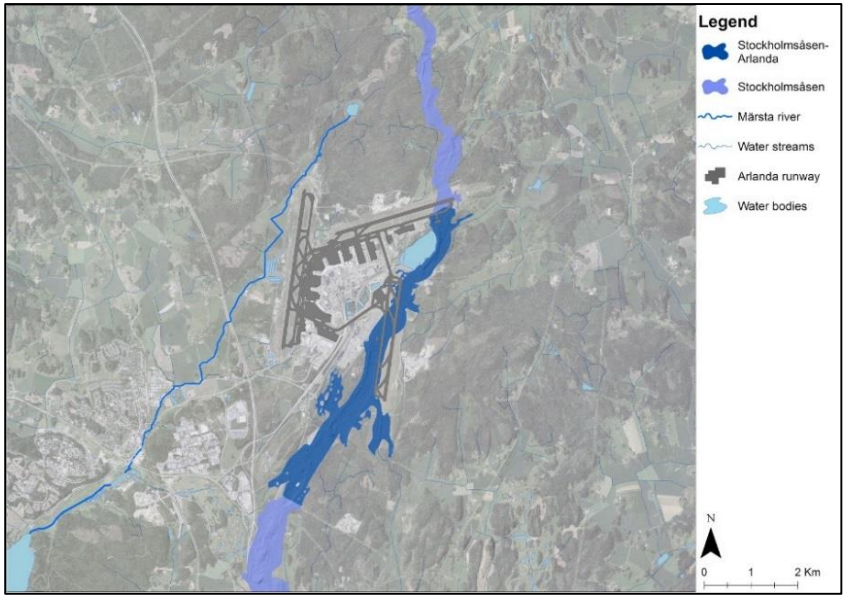

Figure 3.12. Hydrological map over the area surrounding Arlanda, with Stockholmsåsen – Arlanda and Märsta stream. Data collected from Lantmäteriet (Øvereng, 2017).

The water use and management at Stockholm-Arlanda-Airport can be categorised into four:

Drinking water – Swedavia buys 530 000 m^3 yearly of this kind of water, of which 35 per cent is sold further to other external activities in the airport area. From 2015 to 2016 Swedavia had an increase of 99 000 m^3 (15 per cent) of drinking water, but only an increase of 7 per cent of passengers (Vatten & Samhällsteknik, 2011).

Stormwater - Diverted water from precipitation from hard surfaces. Depending on the kind of surface and its properties, the stormwater will contain different kinds of pollutants. The total stormwater flow within the area is calculated to be approximately 8 000 000 m^3 (250 l/s) (Vatten & Samhällsteknik, 2011).

Wastewater – Wastewater from the airport area is disposed of in Swedavia's management systems, before it's diverted to Sigtuna municipality´s sewage grid. It then goes further to Käppala treatment plant. The total amount of wastewater sent back to Käppala treatment plant is 560 000 m^3/year. There is an agreement between Swedavia and Sigtuna municipality stating that Swedavia is responsible for all wastewater from the airport area (Vatten & Samhällsteknik, 2011).

Groundwater – Within the airport area there are groundwater resources in the esker (Stockholmsåsen-Arlanda) aquifer (Figure 3.12). The groundwater accumulation within the airport area is foremost depending on the amount of hard surface area, drainage and leakages into tunnels. The quantity of water in the esker (Stockholmsåsen-Arlanda) is described by VISS (2017) to be abundant and unusually large in the greater parts of the aquifer.

Swedavia is permitted to take as much as 2 500 000 m^3 water per year and no more than 720 m^3/hour (Mark – och Miljödomstolen, M2284-11). However, there needs to be a feedback to the aquifer of 2 500 000 m^3 (Vatten & Samhällsteknik, 2011).

Hard surface areas work as a barrier for the groundwater aquifer, but can also be a danger to the quality of the water. Therefore, it is important to take necessary actions to protect the groundwater. The groundwater in the airport area is located close (1-2 metres) to the surface, which makes it extra vulnerable (Winter et al. 1998). It is impacted by the actions on ground level mostly by increased levels of salts. None of the EU listed substances (Directive 2000/60/EU) or any pesticides have been detected in the groundwater in the area (Vatten & Samhällsteknik, 2011).

Legislation

Within the EU, there are several Directives relevant to water issues. The main one is Directive 2000/60/EC (EU Water Directive), which in Sweden is incorporated in three legislations: 1) Chapter 5 in the Swedish Environmental Code, 2) Regulation 2004:660 and 3) Regulation 2007:825. In EU Directive 2000/60/EU, the main objective is to secure, protect and improve the water within the EU with regards to all lakes, watercourses, coastal water and groundwater. The aim of the Directive is to limit pollution, encourage sustainable water usage and to improve the state of marine ecosystems and ecosystems depending on healthy water bodies. While the original goal was to accomplish this by 2015, it is now changed to 2027 at the latest.

De-icing at airplane stands

The de-icing of airplanes at the stands at Stockholm-Arlanda-Airport is done with propylene glycol (Figure 3.13). However, de-icing cannot take place at every stand. It has to be done in areas where de-icing equipment has been installed. Approximately 10 per cent of the glycol is left on the airplane exterior when it takes off from the runway, and is therefore outside the boundaries of this chapter. Furthermore, 69 per cent is collected from the terminals and first sent to the internal treatment plant and then

Figure 3.13. Picture of de-icing activity at Arlanda Airport (photo by authors).

further to Käppala treatment plant. That leaves 21 per cent that enters the stormwater and may pollute the groundwater and other water recipients (Swedavia, 2017e).

3.6.3.2 Zero Alternative - Impacts

The Zero Alternative, as previously stated, includes the UPA but without expansion in the north. There will *likely* be no significant impact to any of the environmental aspects regarding hydrology and water use.

Mitigation

Mitigation is not needed.

3.6.3.3 Alternative Central – Impacts

Impacts during construction phase

Same as for Alternative North (see below). However, the impact in Alternative Central will not be as great. This is because of the alternative's location on a hard surface area. The amount of forest and green space that has to be removed and covered up is significantly smaller in Alternative Central, and the sensitivity is lower because of this.

A major problem, with respect to stormwater, is the levels of glycol and cadmium received by Käppala treatment plant. Alternative Central will likely have a minor negative impact. Any expansion of the airport will lead to more airplanes. As such there will be more de-icing of airplanes and, thus, more glycol and cadmium in the stormwater. However, in light of climate change and warmer winters, de-icing might not be needed in the same extent as it is today.

It is likely to be a minor negative impact on stormwater during the operation phase of Alternative Central, for the same reasons as in Alternative North. However, in Alternative Central, the impact is not as high. One of the reasons for this is the already existing infrastructure that manage the stormwater today, and it's easier to connect to this rather than building new infrastructure in the north.

The expected increase in precipitation in the future will require the airports to expand their capacity to handle stormwater, and also to prepare for more extremes in precipitation. However, the stormwater in the southern parts of Sweden (where Arlanda is included) will likely contain less chemicals. This is because a heightened mean temperature during winter leads to de-icing being used to a lesser extent. De-icing is estimated by 2050 to be 50-70 per cent lower than in 2007 (SOU, 2007).

Mitigation

Stormwater

Proper planning and scenario building will help the mitigation for dealing with increased stormwater and a higher risk for flooding. Therefore, it is crucial that the developer assess the future before commencing. An important factor to consider is that the mitigation needs to be located need the point of origin, especially concerning the groundwater quality of the area (USGS, 1983). It is also important to set up monitoring of the Stockholm esker to see if there are changes in flow or quantity.

De-icing

The biggest challenge of mitigating the use of glycol is finding a chemical with low biological impact and low oxygen demand. However, Rosenlof (2013) describes a method using IR (infrared radiation), which contains no chemicals and no oxygen for decomposition. This could be a possible solution, but it will be costly. In addition, the future climate is unsure and difficult to predict. For further detail see Chapter 2, section 4.3.

Conclusion

The only difference between Alternative Central and the Alternative Zero is the impact on the groundwater quality. This is due to the properties of the location of this alternative, which is on hard surface area with a minimum of green area.

3.6.3.4 Alternative North - Impacts

Impacts during construction phase

In the construction phase of the North Alternative it is likely that the groundwater quality will be impacted. This is mainly due to the runoff from the construction site, which can be significant. The amount of sediments in this runoff can be as high as 1 000 – 2 000 times higher than from green areas. In a short period of time a construction site can contribute more sediments than what is naturally deposited in about 20 years. This high sedimentation contribution from the construction site can cause physical, chemical and biological harm to the water recipients. In all likelihood, the runoff will also contain hazardous chemicals which will be hard to capture before it runs into lakes, rivers or the groundwater (EPA, 2005).

Materials, paint, oils and solvents are some of the substances that are likely to end up in the water recipients if mitigation measures are not carried out.

Impacts during operation phase

In the North Alternative there will likely be a minor negative impact on the quality of groundwater during the operation phase

due to more use of chemicals in for example maintenance. The quantity of the groundwater will not be affected by the operations. VISS (2017) describes it as abundant in the greater parts of the aquifer. There is a possibility to extract as much as 2 000 – 10 000 m^3/day of groundwater. So even if the terminal's capacity would expand to 70 million yearly passengers, and the activities at Arlanda Airport would increase, there would be no significant impact on the quantity of groundwater. The operation phase is likely to have a minor negative impact on wastewater.

The greatest challenge in this alternative is the stormwater. This is because of the increase in hard surface area that will not allow the surface water to infiltrate. This will increase the surface runoff, that is more likely to contain environmentally hazardous substances (Stockholm Vatten & Avfall, n.d). In Alternative North, this will have a major negative impact due to the area's properties today and the extension in this alternative will not follow the national environmental objective "Groundwater of good quality". Sigtuna Municipality has goals of decreasing the amount of surfaces where water cannot infiltrate (Sigtuna Kommun, 2011), while Swedavia has goals of contributing to a good ecological and chemical status of the surrounding water bodies and rivers (Swedavia, n.d). The drinking water may be minor negatively impacted by operations in this alternative, due to the sensitivity of lake Mälaren (Norrvatten, n.d). However, this is outside the scope of this EIA, so the impact assessment here will be no significant impact.

Conclusion

The biggest impact of Alternative North is the stormwater and the groundwater quality. These two aspects are in close relation to each other, as increased runoff will impact the groundwater quality.

Mitigation

For stormwater and de-icing practices the mitigation measures are the same as for Alternative Central. To mitigate the materials, solvents, oils and paint pollution during the construction it is important that the developer makes defined goals and guidelines for how to the projects is to be carried out, with regards to the coordination of the project. However, the goals and guidelines itself will not mitigate the problem, but good communication between developer and construction workers might. There are steps that are important to minimize the pollutions and construction waste: (1) ask what kind of project is this, in order to limit excess materials (2) ask how is this building going to be built, to get the materials when they are needed (3) ask what resources are needed to build it, what kind of materials and from where (4) inform the workers about the environmental policies (5) follow through, recycle, return materials that are not used or needed, and plan this so less transport from and to the construction site is needed. (6) follow up, create waste statistics to keep control and ask for feedback about how the work has been going.

3.6.4 Noise

In this section we will address construction noise related to the expansion of Arlanda Airport terminals. Hence, noise from airplanes are excluded.

3.6.4.1 Environmental baseline

Swedavia works to ensure that the noise levels around their airports are considered acceptable, in relation to the social benefits provided by air travel and the airport. Some of the measures that Swedavia works with include noise insulation of residences, increased take-off charges for aircrafts that generate higher noise levels and the promotion of "green" solutions. Such solutions include avoidance of densely populated areas upon the aircraft's approach to landing, as well as incorporation of certain methods of manoeuvring. Green approaches require less engine thrust, save fuel and reduce emissions (Swedavia, 2016a).

The extent of the noise varies, depending on the setting and stage of development. During construction, the blasting and foundation work usually cause noise to become markedly noticeable for local residents. At a construction site, the noise depends on the type of machines used. The layout and design of the construction site is crucial, e.g. how the machines are set up, and how transport roads are designed for transport of rubble and freight of building materials (Naturvårdsverket, 2017c).

Noise level requirements are set by the authorities, and in Sweden it is regulated by the Environmental Code. The Swedish Environmental Protection Agency has general advice on how to work with noise during the construction phase. The guideline value for noise levels depends on time of day. There is a maximum sound level for housing, holiday homes and care facilities, between the hours of 22:00-07:00. The chart below, shows that construction noise near housing, holiday homes and offices with quiet activity could reach up to 70 dB outside.

3.6.4.2 Zero Alternative - Impacts

May have minor negative impact due to the sensitivity of the area.

3.6.4.3 Alternative Central - Impacts

Will have minor negative impact. In this alternative they will not need to use the same blasting equipment as in Alternative North. However, the sensitivity of the area is high because of the proximity to passengers.

3.6.4.4 Alternative North - Impacts

According to Naturvårdsverket (2017d), noise levels should not exceed 40 dB in areas where the absence of noise is a significant part of the experience, e.g. in recreational areas. Laggatorp nature reserve is in close proximity to the proposed area for Alternative North, and would be well inside the "buffer zone" for noise, should the expansion go through (Figure 3.14). The 40 dB limit is therefore highly likely to be exceeded, should the construction reach a noise level of 131 dB or more. It is thus concluded that Alternative North will have a major negative impact. In addition, because of difference in topography, Alternative North would require a levelling of the area to be equal to the rest of the existing terminal and runway, which also would generate noise.

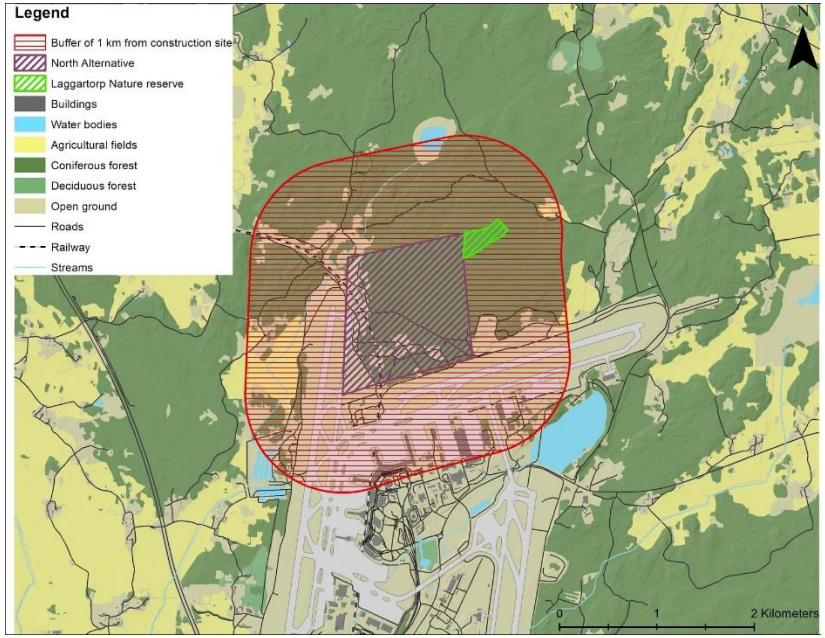

Figure 3.14. Noise map over the area surrounding Alternative North. Within the red buffer zone noise level does not exceed 40 dB. The green zone is Laggatorp nature reserve and the purple zone is Alternative North. Data collected from Lantmäteriet (Øvereng, 2017).

3.6.5 Waste

This section will examine waste generation and waste management at Stockholm-Arlanda Airport.

3.6.5.1 Environmental baseline

The bulk of waste management at Stockholm-Arlanda Airport is issued on contract. The main contractor is Ragn-Sells whom manage all waste except for the grease and oil separator, pipes and treatment works, which are managed by SITA. Within the area of waste management, Swedavia is only responsible for cleaning the airport area, emptying garbage bins and the maintenance cleaning of pipes used for aviation fuel (Swedavia, 2017e). Collection of waste is arranged in a way that encourages recycling.

One essential aspect of waste management at Stockholm Arlanda Airport is *Kretsloppscentralen*. It is a receiving and transhipment facility for waste. It is owned by Swedavia, but managed by Ragn-Sells. The facility is located close to the terminals and is manned daily between 07.00-09.00. All operations within Stockholm Arlanda Airport are allowed to leave waste at Kretsloppscentralen (Swedavia, 2017e). From here, waste is transported to authorised recycling companies and treatment facilities.

All waste from Swedavia's facilities is sorted into four categories: waste for material recycling, waste for energy recovery, waste for hazardous waste and landfill. In Table 3.4 and 3.5 the fractions of waste for material recycling and energy recovery is presented.

Table 3.3. Fractions, recipients and volume of waste for material recycling generated at Stockholm-Arlanda Airport in 2016 (Swedavia, 2017e).

Category/fraction	Recipient	Amount (tons)
Mixed scrap metals	Högbytorp/Västerås	12.41
Grease from grease traps	Henriksdal	243.5
Biodegradable waste	Uppsala	558.16
Glycol residues	Västerås	2516
Plastic containers	Edstippen	229.13
Metal containers	Högbytorp	12.6
Coloured glassware	Högdalen	335.95
Uncoloured glassware	Högdalen	37.26
Packaging materials	Lunda	49.44
Paper	Hallstavik/IL Rosersberg	93.17
Well Papp	Lunda	351.85

Table 3.4. Fractions, recipients and volume of waste for energy recovery generated at Stockholm-Arlanda Airport in 2016 (Swedavia, 2017e).

Category/fraction	Recipient	Amount (tons)
Mixed waste for sorting	Högbytorp Uppsala	12.41
Incendiary operation waste	Uppsala incineration facility/Brista	2718.04
Household waste	Uppsala incineration facility/Brista	1551.49
Sorted wood	Högbytorp/Edst./Brista	34.96

Swedavias ambition is that all waste should be separated at source. Waste generated by the day-to-day business should be sorted in the designated recycling areas. Waste from other operations, such as deconstructions or rebuilding, should be managed by the entrepreneur. In 2016, only a few per cent of all waste went to landfills, whereas the largest part was incinerated and reused as energy. Swedavia's goal is that at least 60 per cent of all waste should be recycled. Hazardous waste often contains substances that can taint soils, water, flora and fauna. Swedavia is therefore keen on handling such waste in a secure manner, so that it cannot spread to the surrounding areas (Swedavia, 2017e).

Hazardous waste

Approximately 400-450 tons of hazardous waste was generated by Swedavia's operation at Arlanda Airport in 2011 (Vatten och Samhällsteknik, 2011). The majority of this waste was sand from road sweeping activities, which generated almost 350-400 tons. According to Swedavia's environmental report for 2016 (Swedavia, 2017e) a total of around 550 tons of hazardous waste was generated that year. Thus, there has been an increase of 100 tons of hazardous waste in 5 years' time. Table 3.6 present the fractions of hazardous waste generated at Stockholm Arlanda Airport in 2016.

Table 3.5. Landfill and hazardous waste generated at Stockholm Arlanda Airport in 2016, including recipient and volume (Swedavia, 2017e).

Category/fraction	Recipient	Amount (tons)
Waste for landfills	Högbytorp	0.17
Lead batteries	Högbytorp	5.99
Batteries	Högbytorp	0.25
Electronics	Elkretsen	34.36
Fluorescent lamps	Högbytorp	2.98
Dissolvent agents	Högbytorp	1.83
Paints	Högbytorp	2.99
Metal hydroxide	Sita Löt	11.32
Oil and fuel filters	Högbytorp	1.26
Spill oil	Högbytorp	8.95
Waste from sand traps	Sita Löt	103.22
Other hazardous waste	Högbytorp	376.84

In areas where a substantial amount of hazardous waste is being generated there are separate cisterns for storing of such waste. This waste is then directly taken care of by the main contractor. Hazardous waste generated elsewhere at the airport is left to Kretsloppscentralen for storing and handling. Most of the hazardous waste is managed by Ragn-Sells and transported to their facility at Högbytorp.

Cabin waste

Every gate at Arlanda has 1-5 containers designated for cabin waste. The amount of containers is determined by type of air traffic at that specific gate. Generally, an international flight of approximately 8-10 hours generates more waste than shorter domestic air travels (Anselius, 2017).

According to Swedavia (2017e), roughly 1,500 tons of cabin waste was generated in 2016. With reference to Anselius (2017) this means that every flight, in general, results in 14 kilos of waste. It is the cleaning staff's responsibility to leave that waste in the designated containers. The containers are thereafter picked up buy waste disposal trucks. All cabin waste from inbound flights to Stockholm Arlanda Airport is delivered to Brista district heating plant in Sigtuna municipality (Anselius, 2017). As part of sustainable development, Swedavia proclaimed a wish to investigate ways to sort and recycle cabin waste.

In-flight catering has a separate waste management system due to the risk of epizootic diseases from international airborne traffic. This waste is separated on-board and upon arrival transported to Uppsala Vatten och Avfall for incineration at their district heating plant (Vatten & Samhällsteknik, 2011).

Construction waste

Swedavia has set regulations that contractors are obliged to follow when carrying out construction work within the airport area (Swedavia, 2013b). First, waste from construction work should be minimized. In order to facilitate this, a plan, containing types of waste, measures to minimize waste, the handling and transport of waste as well as the recipients of hazardous waste, has to be compiled.

Waste management has to follow the airport regulations regarding sorting and handling foreign object debris. When it comes to recycling, *Kretsloppsrådets* guidelines are to be followed. This involves separating hazardous waste, electrical waste, wood, plastics, combustible waste, gypsum, metals, filling material, landfill and mixed waste. The fractions of landfill and mixed waste should be minimized (Swedavia, 2013b). According to Vatten & Samhällsteknik (2011) approximately 400 tons of construction waste was generated in 2011.

Foreign object debris

Foreign object debris, normally referred to as FOD, is defined by the Federal Aviation Administration (2013) as objects that do not belong on the runway, taxiway or apron. Typical items include aircraft parts, tire fragments, nails and luggage parts etc. FOD can also consist of scrap particles from construction work or waste from cleaning the aircrafts. The latter mainly refers to food residue that can attract birds and other animals. Foreign object debris can, when caught by air-movement, cause damage to aircrafts and, on rare occasions, cause accidents. Thus, FOD poses a safety hazard if not taken care of properly.

According to Swedavia (2013c) everyone within the airside area has a responsibility and obligation to remove any foreign objects that can cause damage to aircrafts. Ground service companies are responsible for inspecting the airplane stands before aircrafts arrive and after they depart. The responsibility also includes reporting to the airport personnel in charge, if objects cannot be taken care of immediately. At times of heavy wind, they should also ensure that there is no risk of equipment or other objects to blow away and cause damage to aircrafts, properties and people.

Improvement measures

Swedavia has been taken some measures in order to improve waste management at Stockholm-Arlanda Airport. Amongst these are the following:

- Possibilities for sorting of waste has improved
- Kretsloppscentralen now has two compressors instead of one, which has the possibility to further reduce waste collection from site.
- Handling and storage of hazardous waste has improved
- The main contractor has also improved their supervisory control system, which has enabled an optimization of activities to reduce and improve sorting of waste.

In the environmental impact statement compiled by Vatten & Samhällsteknik (2011) it is concluded that the direct effect of waste on human health and the environment is considered to be small. At the same the airport operation at Arlanda is generating a lot of different types of waste. Considering the amount of waste in 2011 the waste collection system is sufficient in a way that enables a safe handling of waste. However, the environmental impact statement withstands that there is a need to further investigate the possibility of increasing recycling of waste that is now being incinerated.

3.6.5.2 Zero Alternative – Impacts

Impacts during construction phase

Considering UPA, there will still be some construction work in the Zero Alternative, mainly by extending Terminal 5 with an additional pier.

Even though Swedavia has set a goal for minimizing construction waste, there will most likely be some waste generated by construction work. However, since entrepreneurs bear the responsibility to sort and manage waste emerging from construction sites, there will not be a need for Swedavia to increase their waste management during this phase. The waste plan that the entrepreneur has to compile gives Swedavia the opportunity to gain insight into waste generation and management.

During construction it is likely that more hazardous waste will be generated. However, this depends on what type of materials that are being used. E.g. paints, gypsum or metals containing toxic substances are regarded as hazardous materials that can originate from construction work (UK Government, n.d.).

During the construction phase there will be a higher risk of Foreign Object Debris if regulations are not followed.

The northern area is not exploited today and the zero alternative involves no construction or operation at this location.

Impacts during operation phase

Since passenger volumes will somewhat increase in the Zero Alternative, the waste loads will presumably also increase. One of the main challenges with airports is that waste is being generated at various locations, such as terminals, airfields, on-board aircrafts etc. This calls for a holistic and systematic approach to waste management, ensuring that different types of waste end up in their proper waste streams.

Much of the waste generated at Stockholm-Arlanda Airport goes to incineration. The positive aspect is that energy in materials is being reused for heating purposes and electrical production. However, incinerating waste also causes problems (Green Choices, 2017). Gases, as a rest product from the incineration process, may cause air pollutions and contribute to acid rain. Burning plastics produces toxic substances, such as dioxins, while ash from district heating plants can contain heavy metals or other hazardous materials.

Following the discussion on hazardous materials, numbers from 2011 and 2016 indicate an increase of about 100 tons of hazardous waste. Out of that, nearly 170 kilos end up at landfills. Solid waste disposal in landfills is per se a problem. One of the main environmental concerns is gas and leachate generation, which consecutively can lead to groundwater and air pollution, as well as vegetation damage (El-Fadel *et al*. 1997). In addition, waste in landfills can contribute to health hazards and global warming; the latter mainly due to generation of methane gas and carbon dioxide in landfills (EPA, 2017).

Conclusion

There is no indication that the fraction of hazardous waste, and waste destined for landfills, will decrease unless auxiliary measures are taken. Therefore, waste generation and waste management at Stockholm-Arlanda Airport may have a minor negative impact. Yet, it is not regarded as major since hazardous waste at Arlanda is being properly taken care of, thus the sensitivity for the area around Arlanda is considered to be low.

Mitigation

During the construction phase, a protective fence could be set up around the construction site in order to limit the risk of FOD. Furthermore, materials should to a large extent be reused, if possible, to reduce or avoid construction waste going to landfills. Materials or waste that cannot be reused should be recycled. In order to facilitate this, recycling should be possible at the construction site.

Management of waste should follow the waste hierarchy, as described in the EU directive and adopted in the Swedish Environmental Code. According to the five steps in the waste hierarchy, waste should be managed through the following: minimize, reuse, recycling, energy extraction and landfill (Naturvårdsverket, 2016). In order to minimize waste in the operation phase there should be an emphasis on prevention and recycling.

3.6.5.3 Alternative Central - Impacts

Impacts during construction phase

Same as with the Zero Alternative, except for the waste loads being considerable larger. Also, the construction work will be on-going for a longer time period. Similarly, the amount of hazardous waste and risk of FOD will increase. Yet again, since the entrepreneurs are responsible for the waste management there is no need to increase the capacity at e.g. Kretsloppscentralen. Handling of waste should nevertheless be closely monitored by Swedavia because, if not properly managed, the capacity and impression of the airport can be affected.

Impacts during operation phase

As with the Zero Alternative, the amounts of waste from operations will increase. In 2016, an average of around 8 756 tons of waste was generated at Arlanda Airport (Swedavia, 2017d). In the same year, the amount of passengers was 24.7 million, according to Swedavia (2017f). Based on those figures, and assuming that they do not change in the future, every passenger will likely generate 0.35 kilograms of waste, excluding hazardous waste. With passenger numbers around 70 million, a total of 24 815 tons of waste will need to be handled. Overall, there will be an increased pressure on Kretsloppscentralen. Thus, there is a need to increase the capacity and operations substantially.

Concerning cabin waste, every flight generates in average 14 kilos of waste. In a scenario with approximately 70 million passengers, Swedavia (2017b) has calculated that there will be close to 495 000 yearly movements. Assuming that only arrival flights will generate waste at Arlanda, an additional 1 965 tons of waste needs to managed. It is worth noting that none of this waste is being sorted and recycled.

The amount of hazardous waste will most likely increase. On account of this, the fraction of waste going to landfills will presumably also increase. As mentioned above, landfills are a source of methane gas and carbon dioxide. By contributing to landfills one can be said to contribute to greenhouse gas emissions. Swedavia has a set a goal to be climate neutral and compensates for emissions in three areas (Swedavia, 2017g). However, waste ending up at landfills is not one of them.

Conclusion

Considering that the amount of hazardous waste will likely increase, along with an increased fraction of waste for landfills, waste will likely have a major negative impact. Partly, because it strictly goes against Swedavia's own goal of being climate neutral and partly because it is not in line with the environmental objectives

Mitigation

During the construction phase, waste management ought to be streamlined if several entrepreneurs are involved in the construction work. It also requires a long-lasting and robust waste management scheme. Furthermore, active programmes to minimize waste should be adopted. Waste that is inevitably generated should to a large extent be recycled. Sorting of waste at the source is then preferred, e.g. in restaurants, stores etc.

Possibilities to sort and recycle cabin waste should be attended to. This exercise needs to be carried out in cooperation with airlines.

Best practice would be to separate waste on-board aircrafts. The fraction of waste going to landfills should be equal to zero. If not possible, it needs to be compensated for.

3.6.5.4 Alternative North - Impacts

Impacts during construction phase

Since there is no existing structure as a basis for this alternative, the amount of construction waste will likely be abundant. Waste will partly emerge from clear-cutting of forest, explosion residues from removal of rock and rest particles from asphalt spreading.

With the relative location of this alternative in mind, which is close to Runway 2, the risk of Foreign Object Debris may be high if the runway is still in operation. This is because wind emanating from aircrafts can stir up parts from the construction site, if not properly protected. This has the potential to be a safety hazard for air traffic, especially at Runway 2.

Impacts during operation phase

Concerning waste generation in this alternative, it will likely be the same as in Alternative Central. That said, waste management in this alternative involves infrastructural challenges inasmuch as it requires new waste storage in Terminal 6, as well as new routes for waste collection. This will be adding to the challenge of waste emanating from several locations around the airport. Overall, a new waste management scheme will have to be set up in this alternative.

Regarding hazardous waste and waste going to landfills it will probably not be exceedingly different from Alternative Central.

Conclusion

As with Alternative Central, this alternative will likely have a major negative impact. The reason behind it is mainly the increasing amounts of construction waste, hazardous waste and waste ending up at landfills.

Mitigation

During the construction phase, suggested mitigation measures include using the wood residues from clear-cutting of the forest to produce biogas, as well as choosing a design approach with focus on material resource efficiency.

Since this alternative concerns new development of a Terminal 6, waste management should be considered already at the planning stage. In order to reduce waste disposal costs, an optimization of waste management should be implemented. However, emphasis should be on avoiding waste generation through changes in buying and operation processes. Moreover, control of the waste streams is fundamental for successful mitigation. To allow for this, an implementation of a waste management monitoring scheme is suggested.

3.6.6 Cultural heritage

This section will examine the cultural historic environment surrounding Arlanda Airport, with special focus on the terminal expansion.

3.6.6.1 Environmental baseline

The cultural environment constitutes a source for knowledge, sense of identity and quality of life, and as such, should be treated as an integral part in an environmental impact assessment. According to the Heritage Conservation Act (2013), the Swedish cultural environment must be taken into account when planning or constructing new developments:

"The care and preservation of our cultural environment is a matter of national concern. Responsibility for this is shared by all. Both private persons and public authorities must show consideration and care towards the cultural environment. Anyone who plans or carries out work must ensure that damage to the cultural environment is, as far as possible, avoided or limited" (2013:548).

Covered by the Heritage Conservation Act are ancient remains and monuments, cultural heritage buildings (also includes parks, gardens and other installations of cultural historic value) as well as church buildings and sites (2 ch. § 1, 3 ch. § 1-2, 4 ch. § 2). These should be cared for and maintained in such a way that their cultural historic value is not diminished and their appearance and character is not debased.

Arlanda Airport operations have been assessed to affect cultural heritage interests to some extent in connection with construction of infrastructure and buildings. Swedavia (2011b) referred to the use of a thorough planning process and adhering to the Heritage Conservation Act as means to ensure that no harm comes to any significant sites.

Cultural Heritage at Arlanda

Arlanda Airport is embedded in a rich historical landscape, with a continuous occupational history of at least 6 000 years. Among the archaeological evidence uncovered in the area are Stone Age settlements, Bronze Age grave mounds and Iron Age hill forts. A

Viking Age grave site was also discovered along the shores of Lake Halmsjön, and the region is known for its high density of runestones (Anund & Beronius Jörpeland, 2003). It was also around the 1st century AD that Sigtuna city was founded, which is widely perceived as Sweden's first town. Following its central position as a market town and place for the episcopal residence, the area around the city was quickly transformed into several parishes, consisting mostly of agricultural land (Nordström, 1982). Much of this land is now part of Sigtuna municipality. The proposed area for terminal expansion in the north will directly impact two of these parishes: Odensala and Husby-Ärlinghundra (RAA, 2004).

Figure 3.15 shows the finds recorded by the National Heritage Board (RAA) in the Arlanda area. Those directly west of the proposed area in the north were all recorded during excavations in 1979, and therefore a more thorough survey is recommended. In addition, RAA (2017, personal communication, 4 December) was unable to determine at this moment, if the entire proposed northern area had been subject to archaeological surveying. But due to the area's rich, continuous history it would be neglectful to assume that these listed finds are all that is there. However, the

area does not house any standing buildings or parks identified as cultural heritage.

In addition to the ancient remains and historic buildings around Arlanda, there is another point of cultural historic interest at the airport, which is worth taking into consideration. Southeast of the terminal buildings is a hangar housing Arlanda Flygsamlingar – a collection of aircrafts dating from 1917 to recent history. Aside from restoring aircrafts, the collection showcases Swedish aviation history, including Arlanda Airport. Run solely on a voluntary basis, the collection is currently open 10 hours a week or by appointment.

Since Arlanda is an area of national interest, new developments within its borders are only permitted after having been considered in relation to the airport's interests. Therefore, the area around the airport is largely unexploited. This has led to the preservation of sites of cultural historic interest.

Areas of cultural historical interest are in general also popular for recreational activities. Similarly, a natural landscape, such as Laggatorp nature reserve, used for recreational activities can provide a sense of cultural identity and well-being. The noise level and visual environment can greatly affect the personal experience and enjoyment of a place. To what extent it will affect the experience varies depending on the visitor's expectations and the character of the site. In this case, visitors at Arlanda Flygsamlingar could be expected to tolerate increased noise levels from aircrafts, whereas visitors to Laggatorp most likely would be disturbed by it.

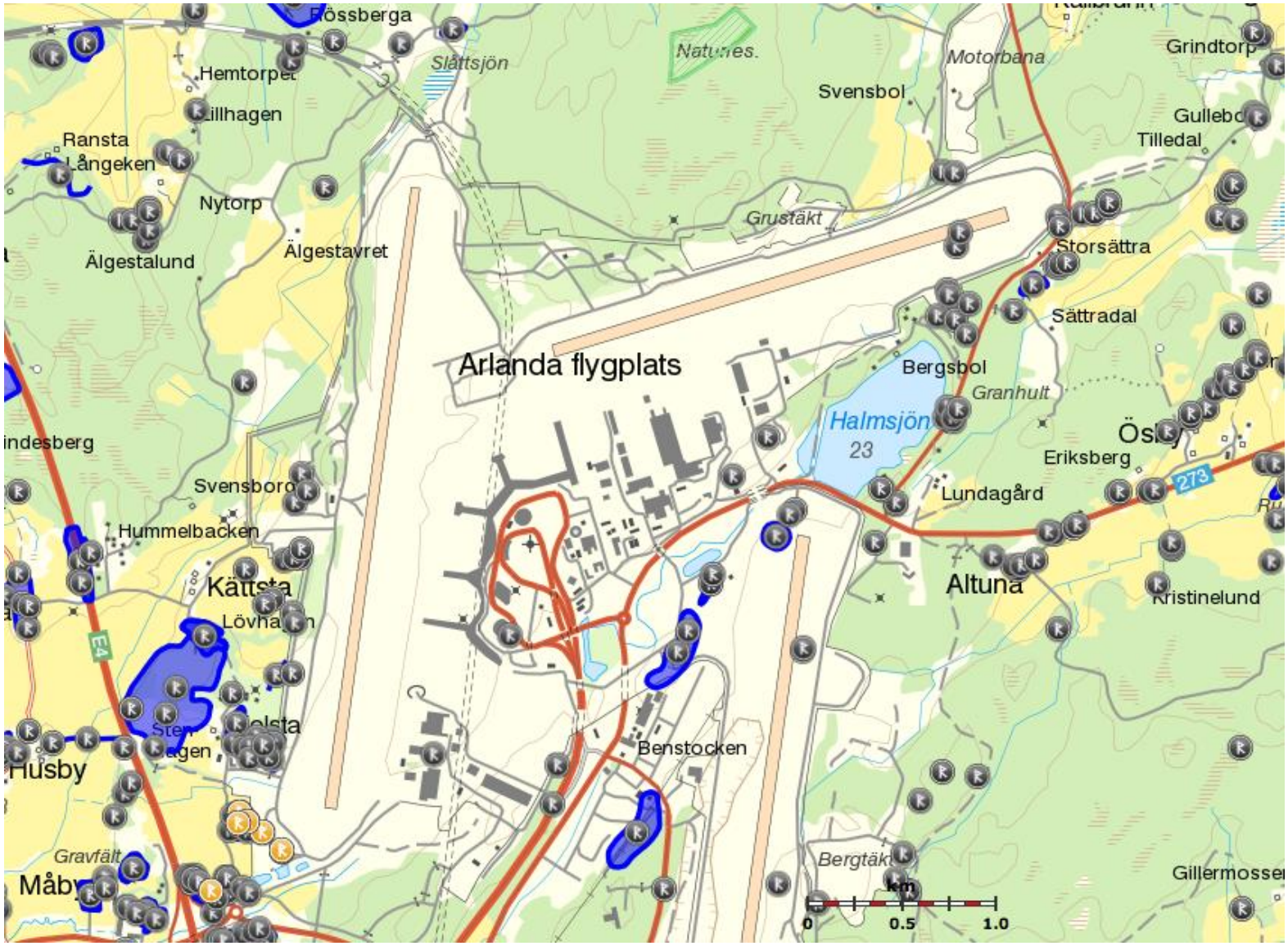

Figure 3.15. The grey and yellow circles represent sites where finds have been recorded by the Swedish National Heritage Board surrounding Arlanda airport (Riksantikvarieämbetet, 2004).

3.6.6.2 Zero Alternative – Impacts

Impacts during construction phase

If the proposed expansion is not carried out, and the construction is limited to the UPA, it is unlikely that any change will occur at the archaeological and cultural historic sites currently surrounding Arlanda Airport. The sites recorded by the Heritage Board north of Runway 1, is presently largely overgrown and not accessible to the public. If the area is not exploited, it is unlikely that they will be examined further, which could lead to degradation. Laggatorp nature reserve will remain untouched, and the experience is likely to remain the same. Arlanda Flygsamlingar, the nearby collection of historic aircrafts, is likely to remain at its current location.

Impacts during operation phase

Once the UPA expansion is complete, it is unlikely to have any additional impacts on the cultural heritage in the area. Due to the maximum capacity of 35 million passengers per year, there will also be no need for additional transport routes. It is also unlikely that Arlanda Flygsamlingar will acquire a significant increase in visitors.

Conclusion

Since Arlanda is a site of national interest, it is unlikely that any further development will take place in the north if the expansion does not go through. Therefore, the area is expected to remain largely the same. The on-going construction for UPA, and its operation phase once completed, is unlikely to have any significant impact on sites of cultural historic interest, nor will it affect the cultural experience. It is therefore assessed that the Zero Alternative will have no significant impact in both the construction and the operation phase.

Mitigation

Mitigation is not necessary.

3.6.6.3 Alternative Central - Impacts

Impacts during construction phase

Since Alternative Central will focus on expanding existing terminal structures, its construction phase is unlikely to disrupt any archaeological sites. Transport of construction material can be achieved through routes already in place, and there are no buildings of cultural historic value in the vicinity to be damaged by pollutants or vibrations from the construction. However, the expansion of Terminal 2 to the east may require the moving of the historic aircraft collection at Arlanda Flygsamlingar. It is likely that a move of this collection will damage the aircrafts, some of which are in a fragile state (J. Forsgren 2017, personal communication, 30 Nov). In addition, the construction of Alternative Central, including an expansion of Terminal 2 in the south, may require a move of Cargo City if additional capacity is desired in the future. Depending on the cargo facilities' new location, it may impact objects of cultural historic interest. Therefore, a complete assessment of the alternative's indirect impacts cannot be made without taking these factors into consideration.

Impacts during operation phase

An increase in passenger capacity through expanding existing terminals, as in Alternative Central, is unlikely to have an impact on the archaeological material in situ within the airport's boundaries. The operation phase of this alternative is also considered unlikely to cause any harm to the cultural landscape directly connected to the airport. However, more travellers at the airport may cause more people to visit Arlanda Flygsamlingar. An increase in funds could lead to higher grade of preservation of historic aircrafts, in both quality and quantity. That would also lead to greater exposure of Sweden's aviation history, and Arlanda's place in it.

Conclusion

The construction phase of Alternative Central is unlikely to directly disrupt any archaeological sites or buildings of cultural historic interest. However, it may require the relocation of Cargo City in the future, and therefore a complete assessment cannot be made. The alternative may also require the relocation of Arlanda Flygsamlingar, which could damage the collection. The operation phase of Alternative Central is unlikely to have any impact on the cultural historic environment. It may lead to additional visitors for Arlanda Flygsamlingar, which could benefit the collection. What has not been measured is the likelihood of erosion on cultural historic objects, such as copper roofs of churches, or the decay of archaeological material in the ground, caused by Arlanda Airport operations. This is something we recommend is carried out before any plans are finalised. Due to this uncertainty it is therefore assessed that the construction phase of the central alternative may have a minor negative impact on the cultural heritage, whereas the operation phase is likely to have no significant impact.

Mitigation

Avoiding the expansion of Terminal 2 in the south would enable Cargo City to remain, thus limiting impact elsewhere. Also, efforts should be made to ensure that the construction of Terminal 2 in the east does not affect Arlanda Flygsamlingar, either directly or by disrupting access routes. An additional measure could be to increase the visibility of the collection, through signage and marketing material, so potential visitors are less likely to be deterred by the construction work in place alongside it.

The expansion of the terminals does also bring opportunity for creating new cultural experiences and heritage for future generations, as will be discussed below, concerning the impacts for Alternative North.

6.3.6.4 Alternative North - Impacts

Impacts during construction phase

The construction of a new terminal in the north is likely to impact the recorded (as well as potentially undiscovered) archaeological sites north of Runway 1. The cultural historic value of these sites has not been assessed, and we are therefore unable to provide a definite answer as to the significance of these impacts. However, access to these sites is limited due to their proximity to the runway, and little care has been given to their preservation. In general, ancient monuments that lack visibility above ground tend

to receive little attention, mainly due to the perceived link between its value and how it is experienced. That, in turn, is a significant limitation, since these are usually the sites that are threatened by destruction and removal (Carlie & Kretz, 1998). In addition, an expansion of Arlanda in the north is likely to disrupt the individual experience at Laggatorp nature reserve, which in turn could lessen the cultural values bestowed upon people by that area of land.

Impacts during operation phase

The impacts of constructing a new terminal in the north, as in Alternative North, will continue throughout the operation phase. In addition, the increase in distance between terminals will require new transport routes. Due to constraint in area, it is likely that these routes will have an impact on a number of sites of cultural historic interest. However, an expansion in the north is unlikely to require the move of Arlanda Flygsamlingar. Rather, an increase in travellers at the airport may lead to more visitors, which in turn could provide better preservation of the collection as well as exposure to Sweden's aviation history.

Conclusion

If Alternative North is carried out, it is likely to damage the sites of cultural historic interest north of Runway 1. There is also the possibility of undiscovered archaeological material in the area. Furthermore, the construction and operation phase of the new terminal is likely to negatively impact the individual cultural experience at Laggatorp nature reserve. That said, it is likely that Arlanda Flygsamlingar would remain in its current location, with a further potential for increased funding. It is therefore assessed that the northern alternative is likely to have a minor negative impact on the cultural heritage.

Mitigation

To lessen the negative impacts of an expansion of Arlanda terminals in the north, we recommend a thorough examination of the sites of cultural historic interest and their condition, as they were last recorded in 1979 (RAA, 2004). In addition, an archaeological survey is recommended for the entire proposed area, due to the evidence of ancient and historic settlements in the vicinity. Preference should also be given to possible transport routes and construction methods that do not directly impact these sites. To lessen any negative impacts on the recreational experience in Laggatorp nature reserve, efforts should be made to keep sufficient distance between the reserve and the new terminal, as discussed in Land use and Noise. Furthermore, planning for new transport routes to the terminal should include a thorough archaeological survey to ensure no harm will be done to any significant sites or objects.

With the construction of a new terminal there is also great opportunity for incorporating the, previously largely anonymous, historic collection of aircrafts at Arlanda Flygsamlingar. Using these historic objects as part of the design is likely to create an increased interest in, and appreciation of, Sweden's aviation history. And as such, it may positively affect the Swedish cultural identity. Through the eyes of visitors and residents alike. In addition, the new terminal could in itself be viewed as a national cultural asset in the future.

3.6.7 Socio-economics

This section will look into the socio-economic conditions associated with the terminals at Arlanda Airport.

3.6.7.1 Environmental baseline

Arlanda airport has a big impact on the employment of the region of Stockholm. At Arlanda today there is 600 different companies with approximately 17 500 employees. In addition to the direct employment, subcontractors and service contractors create around 10 000 job opportunities in the region (Swedavia, 2017b). Table 3.7 gives examples of job categories in association with airports.

Flight travel contributes, to some extent, to increased living standards and alleviates poverty through tourism and trade. In remote areas it can serve as the only means of transportation, hence it contributes to promoting social inclusion (IATA, 2014). According to Swedavia's financial and sustainability report from 2016 there are three main strategies for social development: 1) High degree of safety 2) Developing leadership and companionship 3) Strengthen external business relationships.

To achieve a high degree of safety, Swedavia works with increased digitalisation, centralised airports surveillance and risk- and continuity development. If preclearance routines for flights to USA are imposed at Stockholm-Arlanda Airport, it could mean a separate security check at Terminal 5, in addition to the one already planned for the terminal's expansion. For the on-going development (UPA) of the airport, the demand for safety is even higher. Swedavia needs to plan for several thousand people moving in and out of the airport during the construction phase. Unexpected events in the world means that an increased focus must be put on security, both outside and inside the terminals (Figure 3.16). In addition to these safety measures, Swedavia also has a goal of zero aircraft technical failures or accidents caused by the company.

For the development of the company's leadership and companionship, Swedavia works with a diversity aspiration. This consists of attracting new members of staff with diverse competencies and experiences. Swedavia has a goal of 23 per cent foreign born (today it is 14 per cent), and a more equal sex distribution with 40 per cent women (today it is 65 per cent men and 35 per cent women). The main strategy the company is working with to achieve this, is the incorporation of trainee programmes for both students and job seekers with a diverse background (Swedavia, 2016a).

Figure 3.16. Interior view at Arlanda Terminal 5 (photo by authors)

3.6.7.2 Zero Alternative - Impacts

Impacts during construction phase

There will presumably be an increase of job opportunities for construction workers due to a slight increase in construction work. However, these people will not be employed by Swedavia. As such, it lies beyond the scope of this chapter.

Impacts during operation phase

The Zero Alternative does not imply a significant difference in number of job opportunities at Stockholm-Arlanda Airport. However, a growth of Swedavia's operations will presumably lead to a slight increase in employment.

Adding a new and common security check for passengers departing from Terminal 5 may lead to less queuing times, which would help fulfil Swedavia's goal of punctuality. In addition, it might also lead to increased customer satisfaction (Swedavia, 2016a). A high sense of security for travellers, as well as employees, can be beneficial for human health in terms of less stress and less fear of violence and threat.

Swedavia has applied to the Swedish government regarding the implementation of US preclearance at Arlanda. In order to proceed, further government decisions are required. Although undecided, it seems likely that within the boundaries of the Zero Alternative this will be implemented. The main reason being that there are no legal obstacles against the implementation, as declared by Swedish governmental investigators. Swedavia concluded that initiating a US preclearance system will lead to increased commercial aviation travels between Sweden and the US. This has been said to generate approximately 280 new job opportunities (Swedavia, 2016b).

Conclusion

Impacts weighted together, and regardless of whether a US preclearance system is implemented or not, it is likely that there will be an increase in job opportunities during the operation phase. As such, this alternative will likely have a minor positive impact. There will likely be no significant impact during the construction phase.

3.6.7.3 Alternative Central – Impacts

Impacts during construction phase

In addition to UPA, a further expansion will create more job opportunities for construction workers, though the impact of this will not be assessed in this EIS. However, there will be more construction workers in the terminal area and/or on the apron during this phase. Thus, this poses a safety hazard for the workers' health if safety regulations are not upheld.

Impacts during operation phase

According to Airports Council International Europe (2004), a rule of thumb when calculating employment in airports is that, for every million travellers handled per annum, around 1 000 jobs are created. Assuming a max capacity of 70 million passengers per annum, this would imply approximately an additional 60 000 job opportunities at Arlanda Airport. Moreover, using weighted averages from 25 European airports, Airports Council

International Europe (2004) concludes that for every 1 000 on-site jobs, 1 100 indirect/induced job opportunities are created regionally. For the Arlanda region this would imply that 66 000 job opportunities arise by expanding Arlanda to max capacity of 70 MPPA.

Table 3.6. Categories of employment created by airport operations (Oxford Economic Forecasting, 1999).

Impact category	Definition	Examples
Direct	Employment related to airport operations	Airport operators, security personnel, aircraft services, flight caterers, airline handling agents
Indirect	Employment created by a chain of suppliers of services to the direct activities	Retailing, cleaning staff, food, construction, advertising
Induced	Employment generated by the spending of incomes earned in direct and indirect jobs	Restaurants, retailing, entertainment

As of recently, Swedavia entered into an agreement with the Swedish company Samhall. Samhall aims to create meaningful job opportunities for citizens with disabilities that cause impaired work ability. Increasing the operations at Arlanda will most likely create more of such jobs, which has the potential to promote social inclusion and create value of otherwise socially marginalized groups.

Stockholm-Arlanda Airport is characterized by security awareness. One of the main priorities for Swedavia is to uphold a high level of security. With higher passenger numbers, there will be an increased demand for security checks in order to avoid constrictions. Marin *et al*. (2007) have studied the effects of queueing on airport security. They discovered that as security waiting lines grew, security personnel sped up their inspection on laptops. It did not, however, affect the screening procedures of carry-on luggage or other personal effects. Marin *et al*. (2007) found that this does not have any effect on level of security on-board aircrafts. Moreover, there seems to be no causality between size of airport and level of security. With a high level of security, human health will be similar to the zero alternative, i.e. less stress and less fear of violence and threat.

Conclusion

With respect to increased job opportunities and no presumed significant impact in level of security, this alternative will have a major positive impact.

3.6.7.4 Alternative North - Impacts

Same as Alternative Central.

3.7 Summary of the Environmental impact assessment

The following section presents a summary of the various environmental aspects and their level of impact in relation to the different alternatives and the Swedish Environmental Objectives.

3.7.1 Impact assessment matrix

This matrix summarizes the evaluation of the different alternatives' environmental impacts during the construction (Table 3.7) and operation phase (Table 3.8).

Table 3.7. Impact assessment matrix for the construction phase.

Construction Phase				
Environmental aspect	**Effect**	**Alternative Zero**	**Alternative Central**	**Alternative North**
Air Quality	GHG emissions	**Minor negative impact** Increase of diesel use due to construction machines.	**Minor negative impact** Increase of diesel use due to construction machines.	**Major negative impact** Increase due to diesel use in construction and land removal processes.
	Particulate Matter	**Minor negative impact** Increase of PM due to construction activities.	**Minor negative impact** Increase of PM due to construction activities.	**Major negative impact** Increases due to diesel use in construction and land removal processes
	Other pollutants	**No significant impact**	**Minor negative impact** Increase of diesel use due to construction machines.	**Minor negative impact** Increase of diesel use due to construction machines.
Hydrology and water use	Stormwater	**No significant impact**	**Minor negative impact** Due to increase of hard surfaces	**Major negative impact** Due to increase of hard surfaces in an area which today is all green area.

Construction Phase				
Environmental aspect	**Effect**	**Alternative Zero**	**Alternative Central**	**Alternative North**
	Drinking water	**No significant impact**	**No significant impact**	**No significant impact**
	Waste water	**No significant impact**	**No significant impact**	**No significant impact**
	Groundwater quantity	**No significant impact**	**No significant impact**	**No significant impact**
	Groundwater quality	**No significant impact**	**Minor negative impact** Due to the runoff from the construction**.**	**Major negative impact** Due to the hazardous runoff from the construction.
Land Use	Vegetation	**No significant impact**	**No significant impact**	**Major negative impact** Loss of existing vegetation in the construction area.
	Habitat	**No significant impact**	**No significant impact**	**Major negative impact** Loss of existing habitat in the construction area. Severe disturbance of adjacent habitat.

Construction Phase				
Environmental aspect	**Effect**	**Alternative Zero**	**Alternative Central**	**Alternative North**
	Connectivity/dispersal	**No significant impact**	**No significant impact**	**Major negative impact** Severe or total loss of existing connectivity/dispersal.
	Ecosystem services	**No significant impact**	**No significant impact**	**Major negative impact** Severe or total loss of ESS derived from the construction area.
	Recreation	**No significant impact**	**No significant impact**	**Major negative impact** The exploited area will lose its recreational value and function. Disturbance on adjacent recreation areas.
	Nature reserve	**No significant impact**	**No significant impact**	**Major negative impact** Disturbance and/or area loss.
Waste	Waste generation and management	**Minor negative impact** Likely that more hazardous waste will be generated, the risk for FOD will be slightly higher.	**Major negative impact** Considerably large amounts of construction waste, hazardous waste and waste for landfills. High risk of FOD.	**Major negative impact** Considerably large amounts of construction waste, hazardous waste and waste for landfills. High risk of FOD.
Noise	Noise level	**Minor negative impact** May have minor negative impact due to the sensitivity of the area.	**Minor negative impact** May have minor negative impact due to the sensitivity of the area.	**Major negative impact** Will have major negative impact due to close proximity to nature reserve.

Construction Phase				
Environmental aspect	**Effect**	**Alternative Zero**	**Alternative Central**	**Alternative North**
Cultural heritage	Tangible	**No significant impact**	**Minor negative impact** May cause move of Arlanda Flygsamlingar and Cargo City.	**Minor negative impact** Likely cause damage to sites of cultural historic interest.
	Intangible	**No significant impact**	**No significant impact**	**Minor negative impact** Likely cause disturbance to visitors at Laggatorp nature reserve.
Socio-economics	Jobs and security	**No significant impact**	**No significant impact**	**No significant impact**

Table 3.8. Impact assessment matrix for the operation phase.

Operation Phase				
Environmental aspect	**Effect**	**Alternative Zero**	**Alternative Central**	**Alternative North**
Air Quality	GHG	**No significant impact**	**No significant impact**	**No significant impact**
	Particulate Matter	**No significant impact**	**No significant impact**	**No significant impact**
	Other pollutants	**No significant impact**	**No significant impact**	**No significant impact**

Operation Phase				
Environmental aspect	**Effect**	**Alternative Zero**	**Alternative Central**	**Alternative North**
Hydrology and water use	Stormwater	**No significant impact**	**Minor negative impact** Due to the increase of hard surfaces.	**Major negative impact** Due to the increase of hard surfaces and vegetation loss caused by the construction phase.
	Drinking water	**No significant impact**	**No significant impact**	**No significant impact**
	Wastewater	**No significant impact**	**Minor negative impact** More waste water production.	**Minor negative impact** More waste water production.
	Groundwater quantity	**No significant impact**	**No significant impact**	**No significant impact**
	Groundwater quality	**No significant impact**	**Minor negative impact** Due to surface runoff increase.	**Minor negative impact** Due to surface runoff increase caused by the construction phase
Land Use	Vegetation	**No significant impact**	**No significant impact**	**No significant impact**
	Habitat	**No significant impact**	**No significant impact**	**Minor negative impact** Disturbance on adjacent habitats

Operation Phase				
Environmental aspect	**Effect**	**Alternative Zero**	**Alternative Central**	**Alternative North**
	Connectivity/dispersal	**No significant impact**	**No significant impact**	**Major negative impact** Severe or total hindrance of connectivity/dispersal.
	Ecosystem services	**No significant impact**	**No significant impact**	**Major negative impact** No or few ESS derived from the operation area.
	Recreation	**No significant impact**	**No significant impact**	**Major negative impact** Disturbance on adjacent recreation areas.
	Nature reserve	**No significant impact**	**No significant impact**	**Major negative impact** Major negative disturbance if the operation area is adjacent. Minor negative disturbance if a sufficient buffer zone is preserved between the reserve and the operation area.
Waste	Waste generation and management	**Minor negative impact** Increased generation of hazardous waste and waste for landfills	**Major negative impact** Continued generation of waste, hazardous waste and waste designated for landfills.	**Major negative impact** Continued generation of waste, hazardous waste and waste designated for landfills.
Noise	Noise Level	**No significant impact**	**No significant impact**	**No significant impact**

Operation Phase				
Environmental aspect	**Effect**	**Alternative Zero**	**Alternative Central**	**Alternative North**
Cultural Heritage	Tangible	**No significant impact**	**No significant impact**	**No significant impact**
	Intangible	**No significant impact**	**No significant impact**	**Minor negative impact** Likely cause disturbance to visitors at Laggatorp nature reserve.
Socio-economics	Jobs and Security	**Minor positive impact** A slight increase in working opportunities.	**Major positive impact** Increased job opportunities and no presumed significant impacts in level of security.	**Major positive impact** Increased job opportunities and no presumed significant impacts in level of security.

3.7.2 Impacts in relation to Sweden's Environmental Objectives

This matrix investigates impacts of the Zero Alternative, Alternative Central and Alternative North in relation to Sweden's Environmental Objectives (Table 3.10). The analysis is based on how the impacts relate to the detail statements of the objectives. Both positive and negative impacts are presented.

Table 3.9. Goal achievement matrix regarding Sweden's Environmental Objectives.

Environmental objective	Zero Alternative	Alternative Central	Alternative North
Reduced Climate Impact	**Positive impact** Increased usage of biofuels. **Negative impact** Usage of diesel vehicles in construction, more waste to landfills.	**Positive impact** Increased usage of biofuels. **Negative impact** Usage of diesel vehicles in construction, more waste to landfills.	**Positive impact** Increased usage of biofuels. **Negative impact** Usage of diesel vehicles in construction, more waste to landfills, removal of green areas reduce CO_2 sequestration.
Clean Air	**Negative impact** Emissions of particulate matter during construction, NO_2 emissions from combustion in diesel vehicles, generation of tropospheric ozone by NO_2 emissions.	**Negative impact** Emissions of particulate matter during construction, NO_2 emissions from combustion in diesel vehicles, generation of tropospheric ozone by NO_2 emissions.	**Negative impact** Emissions of particulate matter during construction, NO_2 emissions from combustion in diesel vehicles, generation of tropospheric ozone by NO_2 emissions.
Natural Acidification Only	**No significant impacts**	**No significant impacts**	**No significant impacts**

A Non-Toxic Environment	**Negative impact** Increased generation of hazardous materials.	**Negative impact** Increased generation of hazardous materials.	**Negative impact** Increased generation of hazardous materials.
A Protective Ozone Layer	**No significant impacts**	**No significant impacts**	**No significant impacts**
A Safe Radiation Environment	**No significant impacts**	**No significant impacts**	**No significant impacts**
Zero Eutrophication	**No significant impacts**	**No significant impact**	**No significant impact**
Flourishing Lakes and Streams	**No significant impacts**	**Negative impact** Risk of Stockholmsåsen-Arlanda's chemical status changing from satisfactory due to leakage of contaminated water, risk of Märsta stream to become polluted.	**Negative impact** Risk of Stockholmsåsen-Arlanda's chemical status changing from satisfactory due to leakage of contaminated water, risk of Märsta stream to become polluted.
Good-Quality Groundwater	**Negative impact** Risk of ground water pollution during construction.	**Negative impact** Risk of ground water pollution during construction.	**Negative impact** Risk of extensive ground water pollution during construction.
A Balanced Marine Environment, Flourishing Coastal Areas and Archipelagos	**No significant impacts**	**No significant impacts**	**No significant impacts**
Thriving Wetlands	**No significant impacts**	**No significant impacts**	**Negative impact** Drainage of wetlands.
Sustainable Forest	**No significant impacts**	**No significant impacts**	**Negative impact** Clear-cutting of forest will lead to less connectivity, ecosystem disturbances and ecosystem services depletion.

A Varied Agricultural Landscape	**No significant impacts**	**No significant impacts**	**No significant impacts**
A Magnificent Mountain Landscape	**No significant impacts**	**No significant impacts**	**No significant impacts**
A Good Built Environment	**Positive impact** Improved aviation infrastructure. **Negative impact** Noise affecting people residing in the terminal area, consequences of particulate matter on human health, insufficient sustainable waste management with respect to minimizing and recycling waste.	**Positive impact** Improved aviation infrastructure. **Negative impact** Noise affecting people residing in the terminal area, consequences of particulate matter on human health, insufficient sustainable waste management with respect to minimizing and recycling waste.	**Positive impact** Improved aviation infrastructure. **Negative impact** Noise affecting people residing in the terminal area, consequences of particulate matter on human health, insufficient sustainable waste management with respect to minimizing and recycling waste.
A Rich Diversity of Plant and Animal Life	**Negative impact** Dust from construction can negatively affect living matter.	**Negative impact** Dust from construction affect living matter negatively, polluted streams adversely affect aquatic ecosystems, noise disturbing animal life.	**Negative impact** Habitat destruction and less dispersal possibilities for plants and animals, dust from construction affect living matter negatively, polluted streams adversely affect aquatic ecosystems, noise disturbing animal life.

3.7.3 Discussion

In this section a discussion on the environmental impact assessment process will be presented. This discussion will include the methods applied, the constraints of the study and a comparison of alternatives with a final conclusion.

3.7.3.1 Method discussion

A checklist based on a review of several international airport EIAs was used as a method for impact identification. This allowed for prioritization based on previous environmental impact assessments. However, the level of detail in Swedavia´s Draft Masterplan for Arlanda Airport is not comparable with EIAs for other airports in the planning and development phase, and it is also difficult to find EIAs exclusively for terminal expansions. Communication with Swedavia was also helpful in gaining more insight into proposed development plans, and helped clarify certain aspects that might have been overlooked if only the review of international airport EIAs had been used.

For impact assessment, the literature review and map overlays were some of the approaches that laid the foundation for the estimations of sensitivity and magnitude. To categorise and present the analysis, a qualitative matrix was used. Due to the lack of detail in terms of size, location, techniques and others characteristics concerning the future terminal, the uncertainty is too high to carry out numerical assessments. Nevertheless, a qualitative approach is presented. The matrix has the potential to inform on the main risks and most important environmental issues related to the planned expansion of the Arlanda terminals (Glasson *et al.*, 2013).

It is important to mention that this EIA is not typical, since the terminal expansion is only in the early stages of the planning phase. The methods for impact assessment are based on the time, resources and level of detail available. In this particular case, we were not able to incorporate public participation or interviews with important stakeholders. Nevertheless, some communication with the Swedavia team helped in guiding the impact assessment analysis.

3.7.3.2 Uncertainties in EIA

Environmental impact assessments are always associated with uncertainties. One general issue of uncertainty relates to the future demand for air travel. According to Swedavia (2017b), the demand increased by 5.3 per cent in 2016 for the whole of Sweden. However, external factors such as societal changes, environmental awareness, technological advances and carbon taxes can influence the demand in the future. If the demand for air travel will increase and, if so, in what way, is highly uncertain.

This chapter assumes a maximum expansion of 70 MPPA, as suggested in the Arlanda Draft Masterplan (2017b), when assessing the environmental impacts. This enables a broad coverage of assessment.

Environmental issues become a problem when society determines that they are. As such, one uncertainty is in what way the environmental impacts assessed in this chapter will be valued in the future. Thresholds could change and new parameters might have to be considered. With respect to this, the impacts identified in this chapter might be different had they been identified at another time.

Other concerns of uncertainty in the EIA process developed during impact assessment and prediction. The assessment and prediction of impacts is a result of the information and data that was available when this chapter was compiled. Thus, the evaluation of impacts is largely determined by the quality of available data. Consequently, the significance and probability of impacts may be assessed differently should new knowledge arise.

Lastly, one uncertainty worth mentioning is the absence of a detailed plan concerning the expansion of Arlanda. Thus, the environmental assessments in this chapter is largely based on the investigations presented in the Arlanda Draft Masterplan (Swedavia, 2017b). To what extent the draft and the final plan will differ is uncertain at the time this chapter was compiled.

In order to manage uncertainty, this chapter has used proven methods to identify, predict and assess environmental impacts. Also, the assumptions underpinning the predictions have been clearly stated. This is one way that this chapter has adopted transparency. Furthermore, the methods used in this EIA have been thoroughly described and explained, and are thus open for evaluation. Concerning the lack of data, extensive research has been made, and where data has been missing proxies have been used when possible.

3.7.3.3 Comparison of alternatives

In 2017, Swedavia compiled a Draft Masterplan investigating options for expanding the operations at Stockholm-Arlanda Airport. Part of that investigation concerns an expansion of the terminal structure. Swedavia identified five different geographical locations. Out of those five, only two met the requirements set for a new terminal area. In accordance with the Draft Masterplan, this chapter has examined an alternative to expand centrally (Alternative Central), in the already existing terminal structure, and an alternative to expand northwards (Alternative North), by building a Terminal 6.

By developing Alternative Central, existing transport infrastructure can be used. Also, in terms of water and electricity grid, the area is already covered. This differs from Alternative North, where there is no existing transport, water or electrical infrastructure. The infrastructural capacity of Alternative Central is, however, not known. As such, investments in infrastructure might be required no matter what alternative is chosen. That said, Alternative North would also require traffic rerouting, including a new station for Arlanda Express.

Alternative Central implies that airport operations will continue in the area during construction. Merging construction and operations might prove to be a logistical challenge that can lead to untimely capacity reductions. Constructing in already built areas can also cause disturbances, which can affect people's perception of the airport. Constant changes and loss of aesthetics will likely lead to lower customer satisfaction. However, one benefit of expanding the existing terminal structure is that, when finished, the transport distance for passengers' in-between gates and terminals will be shorter and more straightforward.

In terms of passenger capacity, Alternative North has the potential to handle more than 70 million passengers per annum, whereas Alternative Central cannot. With respect to this, an expansion north might be inevitable depending on the future demand for air travels. Thus, choosing Alternative North might prove to be a more cost-effective and long-term solution.

Considering land-use changes, Alternative North will lead to a more extensive transformation of the landscape compared to Alternative Central. The area designated for expanding Alternative Central is already consisting of buildings or paved surfaces, whereas the area in the north consists of coniferous forest and wetlands. Building a new terminal in the north will inevitably lead to a loss of green spaces. In turn, this will have a negative effect on plant and animal life, due to habitat destruction. The consequence of this will be a potential loss of biodiversity.

An expansion in the north also means that the nearby nature reserve Laggatorp will be adversely affected. The abundance of very old trees with long continuity in the area serves as an important habitat for both flora and fauna. Even though the reserve might not be directly affected, a development in the area could have potentially significant indirect effects on animals and plants, mainly through noise, light pollution and vibrations. Exploiting this area could also affect the inherent, and more intangible, values of the nature reserve. The goal achievement of Sweden's Environmental Objectives concerning Sustainable Forests, Thriving Wetlands and a Rich Diversity of Plant and Animal Life is considered to be low in Alternative North.

In terms of air quality, adverse environmental impacts are expected to occur during the construction phase in both Alternative North and Alternative Central. However, the impacts are more significant in Alternative North. The transformation required to expand the airport operations in the north is more dramatic, mainly through more land clearing, which will lead to more material movement, machinery work and thus increased fuel requirements. The effect of this will be more pollutants, particulate matter and GHG emissions from construction in Alternative North. Such emissions can lead to a decreased ecological quality of the surrounding areas which, in turn, can lead to consequences such as ecosystem degradation and health related problems for humans.

Additional GHG emissions due to construction work in both Alternative Central and North will result in Swedavia having to compensate for these emissions if they want to keep their position of being climate neutral. In regard to the operation phase, no significant impacts on air quality or GHG emissions can been seen in any of the two alternatives. Overall, the goal achievement of Sweden's Environmental Objectives Reduced Climate Impact, Clean Air and Good Built Environment is during the construction phase considered to be low, whilst in the operation phase it is considered to be high.

Concerning noise, the impact will be more significant in Alternative North than in Alternative Central. Once again, it is mostly related to the construction phase and since construction will be more extensive in the north it is likely that the effect will be more considerable. In addition, the nature reserve Laggatorp, close to Alternative North, has more restrictive thresholds for noise, resulting in a higher sensitivity of this area.

Increased levels of noise can potentially affect the integrity of the surrounding ecosystems and lead to a reduced ecological quality of the nature reserve, diminishing its conservation value as a consequence. During the operation phase, noise can also become more problematic in Alternative North compared to Alternative Central. This is mainly due to higher sensitivity of the area, expressed in more restrictive thresholds for noise.

Comparing the impact on cultural heritage between the two alternatives is difficult since the area in the north has not yet been thoroughly investigated. In other words, the area designated for Alternative North is an unexplored site. Since archaeological surveys carried out in the surrounding area have uncovered a vast amount of ancient monuments, it is highly likely that the development area also contains potentially important cultural values. With respect to this, the impact on cultural heritage is considered to be somewhat more significant in Alternative North. A potential loss of cultural heritage can affect the legitimacy of the project.

Since Alternative Central already is an exploited site with mainly hard surfaces, an expansion of the airport operations will not lead to any major impacts. Considering an expansion in the north the impacts will be more severe. By removing green spaces, the hydrological cycle is altered, which affects the water dynamics in the area. Consequently, the ecosystem integrity can be affected.

Since the region surrounding Arlanda has abundant water resources, an expansion of the airport operations, regardless of alternative, will not have an effect on groundwater quantity. However, leakages from Arlanda can potentially affect groundwater quality.

One impact that is not seemingly different, in terms of significance between the alternatives, is waste. During the operation phase, waste generation is dependent on the amount of passengers and flights arriving at Arlanda, which is the same in both Alternative Central and North. Following construction, more construction waste, hazardous waste and waste designated for landfills will increase. In light of this, waste generation at Arlanda Airport will further compromise the achievement of the Environmental Objectives: A Good Built Environment, A Non-Toxic Environment and Reduced Climate Impact.

The only significant positive impact is the increased amount job opportunities that follows an expansion of the airport operations. More passengers result in more personnel requirements and commerce opportunities. This has the potential to boost the regional economy, by increasing wages and consumption capacity.

Expanding the operations at Stockholm-Arlanda Airport is one step in the direction towards becoming a Scandinavian Transport Hub. However, as previously mentioned, this does not come without its consequences. Acknowledging that airport operations seldom are completely environmentally friendly is an important step towards becoming more sustainable. It should be at the core of the organization to not only account for but also to reduce impacts from the aviation industry as a whole.

3.7.3.4 Conclusion

By having performed an Environmental Impact Assessment on the different expansion alternatives of Stockholm-Arlanda Airport, we recommend an expansion of Alternative Central. Considering the environmental impacts, the Zero Alternative represents the option with least negative effects. However, the Zero Alternative is not compatible with Swedavia's goal of becoming a Scandinavian Transport Hub. Alternative Central will allow for a maximum capacity of 70 million passengers per year and is therefore congruent with Swedavia's projection of future capacity requirements. Nevertheless, if the air travel demand exceeds 70 million passengers an expansion northward is inevitable.

Alternative Central will most likely have less significant environmental impacts in comparison with Alternative North. This is mainly because this area has been previously exploited and already consists of hard paved surfaces. Thus, the transformation will not be as extensive as in Alternative North. Furthermore, the proximity to existing infrastructure gives this alternative a big advantage over the other since it does not require traffic rerouting or extension of the power and water grid. From a traveller perspective, a conjoined terminal structure will result in shorter transferring distances.

The reason behind why Alternative North has more environmental impacts is mainly due to the high sensitivity of the area with proximity to wetlands and nature reserves. Moreover, this alternative requires transformation of green spaces into built areas. It is also an unexplored site that can contain important cultural values. With environmental aspects in mind Alternative Central is regarded as the best way forward for Swedavia to expand their operations.

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