Perceived Accessibility by Air Transportation:

Determinants, Heterogeneity, and Climate Policy Implications

Sihyun Yoo

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Content

Summary

Air transportation plays a fundamental role in modern society by enabling access to opportunities, activities, and destinations located over long distances. By overcoming geographical barriers and substantially reducing travel time, aviation expands individuals' spatial reach and facilitates participation in economic, social, and recreational activities worldwide. However, despite these societal benefits, aviation is also associated with significant environmental impacts, particularly greenhouse gas emissions. While technological improvements have increased fuel efficiency and operational performance, the overall climate impact of aviation continues to grow due to increasing demand for air travel driven by rising incomes, population growth, and declining ticket prices. Existing policy measures, such as emissions trading schemes and offsetting mechanisms, have been criticized for being insufficient to achieve substantial reductions in aviation's climate impact. Consequently, stronger climate policies are likely to be required.

Since air transportation primarily functions as a means of accessing distant opportunities, understanding how climate policies affect air travelers requires a framework that goes beyond purely technical or operational assessments of aviation systems. Accessibility theory provides such a framework by conceptualizing transportation as a means of enabling access to desired activities and opportunities. The diverse factors that influence accessibility can be organized into transport, land-use, temporal, and individual components of accessibility. More recently, the concept of perceived accessibility has emerged, emphasizing that accessibility is experienced differently by individuals depending on their preferences, abilities, perceptions, and constraints. This thesis focuses specifically on perceived accessibility by air transportation (PAA), referring to how travelers perceive their ability to access desired long-distance opportunities by air travel.

The thesis identifies several important gaps in the literature. While accessibility has been extensively studied in local and regional transportation contexts, accessibility by air

transportation has received comparatively limited attention. Existing studies largely focus on 'objective' measures based on transportation networks or spatial distributions of opportunities, often emphasizing connectivity and travel impedance while neglecting travelers' perceptions and preferences. Furthermore, although individual air travel attributes such as travel time and cost have been widely studied in aviation research, they have rarely been examined within an integrated accessibility framework that simultaneously considers transportation characteristics, destination attractiveness, and individual perceptions. The determinants of PAA, their relative importance, and the heterogeneity among travelers in how accessibility is perceived remain insufficiently understood.

The aim of this thesis is therefore to develop a comprehensive understanding of perceived accessibility by air transportation and to analyze how aviation climate policies may affect it. The thesis addresses both scientific and societal challenges. Scientifically, it contributes to accessibility research by extending accessibility theory into the context of long-distance air travel and by incorporating perceived accessibility into air transportation studies. Societally, it contributes to ongoing discussions regarding aviation climate policy by providing insights into how policy measures aimed at reducing aviation emissions may affect travelers' access to long-distance opportunities.

To achieve these aims, the thesis adopts a multi-method research approach consisting of three main stages. First, a systematic literature review is conducted to examine how accessibility has been studied in the context of air transportation (Chapter 2). The review identifies dominant research approaches, accessibility perspectives, theoretical scopes, and research gaps. The findings reveal that accessibility research in aviation has been dominated by infrastructure-based and location-based perspectives, with limited attention to utility-based and person-based approaches. Existing studies largely focus on the transport and land-use components of accessibility, while the temporal and individual components remain underexplored. Furthermore, utility-based approaches aiming to study perceived accessibility have been largely absent from the literature. The literature demonstrates that 'objective' accessibility measures and perceived accessibility measures can yield different results. The review therefore highlights the need for studies that explicitly investigate PAA and the individual component.

Second, an exploratory qualitative study using focus group discussions is conducted to investigate how travelers conceptualize accessibility by air transportation (Chapter 3). The findings reveal that PAA is shaped not only by characteristics of transportation and destinations—such as travel time, costs, transfers, main points of attraction of destinations and activities at destinations—but also by how travelers value such characteristics, their familiarity with the destination, and whether they perceive the journey as worthwhile to engage in desired activities there. The study also demonstrates substantial heterogeneity among travelers. Differences emerge depending on travel purpose, socio-demographic characteristics, financial resources, travel experience, and personal preferences. In particular, distinctions are observed among visiting relatives, business travel and leisure travel. Of these three travel motives, visiting relatives is observed to be the activity with the highest importance in terms of quality of life and the least substitutable. Online means are insufficient to substitute in-person contact with relatives and the destinations where the activity can take place is relatively fixed. The importance of business travel and leisure travel for quality of life, as well as substitutability of

activities involved in the two travel motives varied across individuals. From the perspective of individuals, leisure travel is perceived as more optional and substitutable in various ways, and responsive to changes in travel conditions and costs. These findings provide the conceptual foundation for the quantitative analysis that is reported in Chapter 4 of this thesis.

Third, the thesis quantitatively analyzes the determinants of PAA using a utility-based modeling framework (Chapter 4). The empirical analysis focuses on leisure air travel by Dutch travelers, as leisure travel is considered the most flexible and policy-sensitive form of air travel. The study combines a destination attractiveness rating experiment with a stated choice experiment involving vacation destination selection. Latent class choice modeling and regression analysis are employed to estimate the relative importance of destination attractiveness and travel impedance factors, while also capturing heterogeneity among travelers.

The results demonstrate that travelers make trade-offs between destination attractiveness and the generalized costs associated with travel. Travel costs, travel time, and required prearrangements negatively affect perceived accessibility, while attractive destination characteristics positively influence it. However, the importance of these factors varies considerably across travelers, indicating substantial heterogeneity in perceptions of accessibility. Some travelers are highly sensitive to travel time or risk of inconvenience, whereas others place greater importance on destination characteristics and are willing to accept higher travel burdens to access preferred destinations.

The findings also have important implications for aviation climate policy. Policies that aim to reduce aviation emissions through market-based measures, such as carbon pricing, are likely to affect perceived accessibility by increasing the generalized costs of air travel. However, market-based measures currently planned and implemented have a marginal effect on PAA of leisure travel. Both the proportion of aviation greenhouse gases subjected to be offset, and historic carbon prices in compliance markets are too low to be effective for behavioral intervention of leisure air travelers. Furthermore, credits from the cap-and-trade market are based on compliance with emissions caps rather than direct reductions or avoidance of emissions, providing no guarantee of absolute emissions reduction if behavioral change is unsuccessful. The thesis argues that substantially higher carbon prices are required for effective behavioral intervention in leisure air travel. Policy makers could therefore consider mandating the use of carbon removal or avoidance credits to fully offset aviation carbon emissions from leisure air travel. Implementing such a policy could further offset the climate impact of aviation by funding carbon removal or emissions-avoidance projects.

The results regarding PAA further reveal that the impact of high-cost carbon credits on PAA of leisure air travel may not be as severe as previously anticipated. If long-distance air travel is to become less common in general, the loss in utility from having to spend vacations at nearby destinations or traveling less frequently by air for vacations may be smaller than anticipated when positionality (the value of a good or service being influenced by the behavior of others) is considered. In other words: people mind less if they fly less often or to farther destinations, as long as others do the same. Furthermore, if absolute reduction in aviation climate impact is achieved through carbon removal or emissions-avoidance credits and related behavioral changes, policymakers can seek measures to partially restore PAA by improving other aspects

of leisure air travel, such as enhancing schedule reliability or reducing necessary steps for cross-border travels through negotiating simplified tourism border control processes with countries frequented by leisure air travelers.

Overall, this thesis contributes to both accessibility research and aviation policy discussions by developing a conceptual and empirical framework for perceived accessibility by air transportation. It provides insights suggesting that accessibility in the context of air travel cannot be fully understood through 'objective' transport and spatial indicators alone, but must also account for travelers' perceptions, preferences, and trade-offs. By integrating accessibility theory, perceived accessibility, and utility-based modeling, the thesis provides new insights into how air travelers evaluate access to long-distance opportunities and how climate policies may influence these evaluations.

Samenvatting

De luchtvaart speelt een fundamentele rol in de moderne samenleving door activiteiten en bestemmingen die zich over grote afstanden bevinden binnen bereik te brengen. Door geografische barrières te overwinnen en reistijden aanzienlijk te verkorten, vergroot de luchtvaart het ruimtelijke bereik van individuen en faciliteert zij deelname aan economische, sociale en recreatieve activiteiten wereldwijd. Ondanks deze maatschappelijke voordelen gaat de luchtvaart echter ook gepaard met aanzienlijke milieueffecten, in het bijzonder de uitstoot van broeikasgassen. Hoewel technologische verbeteringen hebben geleid tot een hogere brandstofefficiëntie en betere operationele prestaties, blijft de totale klimaatimpact van de luchtvaart toenemen als gevolg van de groeiende vraag naar vliegreizen, gedreven door stijgende inkomens, bevolkingsgroei en dalende ticketprijzen. Bestaande beleidsmaatregelen, zoals emissiehandelssystemen en compensatiemechanismen, zijn bekritiseerd omdat zij onvoldoende zouden zijn om substantiële verminderingen van de klimaatimpact van de luchtvaart te realiseren. Daarom zullen waarschijnlijk strengere klimaatmaatregelen noodzakelijk zijn. Aangezien luchtvaart in de eerste plaats functioneert als een middel om verre bestemmingen en activiteiten te bereiken, vereist inzicht in de effecten van klimaatbeleid op vliegreizigers een kader dat verder gaat dan louter technische of operationele analyses van luchtvaartsystemen. De bereikbaarheidstheorie biedt een dergelijk kader door transport te conceptualiseren als een middel om gewenste activiteiten te bereiken. De diverse factoren die bereikbaarheid beïnvloeden kunnen worden onderverdeeld in transport-, ruimtelijke, temporele en individuele componenten van bereikbaarheid. Meer recent is het concept van ervaren bereikbaarheid ontstaan, waarbij wordt benadrukt dat bereikbaarheid door individuen verschillend wordt ervaren afhankelijk van hun voorkeuren, mogelijkheden, percepties en beperkingen. Dit proefschrift richt zich specifiek op ervaren bereikbaarheid via luchtvaart (*perceived accessibility by air transportation; PAA*), waarmee wordt verwezen naar de wijze

waarop reizigers hun mogelijkheid ervaren om via vliegreizen gewenste activiteiten op lange afstand te bereiken.

Het proefschrift identificeert verschillende belangrijke lacunes in de literatuur. Hoewel bereikbaarheid uitgebreid is bestudeerd in lokale en regionale contexten, heeft bereikbaarheid via luchtvervoer relatief beperkte aandacht gekregen. Bestaande studies richten zich voornamelijk op 'objectieve' maatstaven gebaseerd op transportnetwerken en ruimtelijke spreiding van mogelijke bestemmingen, waarbij vaak de nadruk ligt op connectiviteit en reisweerstand, terwijl percepties en voorkeuren van reizigers grotendeels buiten beschouwing blijven. Bovendien zijn individuele kenmerken van vliegreizen, zoals reistijd en kosten, weliswaar veelvuldig onderzocht binnen luchtvaartonderzoek, maar zelden bestudeerd binnen een geïntegreerd bereikbaarheidskader dat gelijktijdig rekening houdt met transportkenmerken, aantrekkelijkheid van bestemmingen en individuele percepties. De determinanten van PAA, hun relatieve belang en de verschillen tussen reizigers in de wijze waarop bereikbaarheid wordt ervaren, zijn nog onvoldoende begrepen.

Het doel van dit proefschrift is daarom om een uitgebreid inzicht te ontwikkelen in ervaren bereikbaarheid via luchtvaart en om te analyseren hoe luchtvaart gerelateerd klimaatbeleid deze bereikbaarheid kan beïnvloeden. Het proefschrift adresseert zowel wetenschappelijke als maatschappelijke vraagstukken. Wetenschappelijk draagt het bij aan bereikbaarheidsonderzoek door bereikbaarheidstheorie uit te breiden naar de context van langeafstandsluchtvervoer en door ervaren bereikbaarheid te integreren in luchtvaartstudies. Maatschappelijk draagt het bij aan het debat over klimaatbeleid voor de luchtvaart door inzicht te bieden in de wijze waarop beleidsmaatregelen gericht op het verminderen van luchtvaartemissies het bereik van reizigers tot kansen en activiteiten op lange afstand kunnen beïnvloeden.

Om deze doelstellingen te bereiken hanteert het proefschrift een multi-methodische onderzoeksaanpak bestaande uit drie hoofdfasen. Ten eerste wordt een systematische literatuurstudie uitgevoerd om te onderzoeken hoe bereikbaarheid is bestudeerd binnen de context van de luchtvaart (hoofdstuk 2). De review identificeert dominante onderzoeksbenaderingen, bereikbaarheidsperspectieven, theoretische reikwijdtes en lacunes in het onderzoek. De bevindingen tonen aan dat bereikbaarheidsonderzoek binnen de luchtvaart voornamelijk wordt gedomineerd door infrastructuurgebaseerde en locatiegebaseerde perspectieven, terwijl nuts- en persoonsgerichte benaderingen beperkte aandacht hebben gekregen. Bestaande studies richten zich hoofdzakelijk op de transport- en ruimtelijke componenten van bereikbaarheid, terwijl de temporele en individuele componenten onderbelicht blijven. Bovendien blijken nutbenaderingen gericht op ervaren bereikbaarheid grotendeels afwezig in de literatuur. De literatuur laat zien dat 'objectieve' bereikbaarheidsmaatstaven en ervaren bereikbaarheidsmaatstaven tot verschillende uitkomsten kunnen leiden. De review benadrukt daarom de noodzaak van studies die expliciet PAA en de individuele component onderzoeken.

Ten tweede (hoofdstuk 3) wordt een exploratieve kwalitatieve studie uitgevoerd met behulp van focusgroepdiscussies om te onderzoeken hoe reizigers bereikbaarheid via luchtvaart conceptualiseren. De bevindingen tonen aan dat PAA niet alleen wordt bepaald door kenmerken van transport en bestemmingen, zoals reistijd, kosten, overstappen, belangrijkste attracties van

bestemmingen en activiteiten op bestemmingen, maar ook door de wijze waarop reizigers dergelijke kenmerken waarderen, hun bekendheid met bestemmingen en de mate waarin zij de reis de moeite waard achten om gewenste activiteiten op de bestemming uit te voeren. De studie toont daarnaast aan dat er aanzienlijke verschillen zijn tussen reizigers. Verschillen doen zich voor afhankelijk van reisdoel, sociaal-demografische kenmerken, financiële middelen, reiservaring en persoonlijke voorkeuren. In het bijzonder worden verschillen waargenomen tussen familiebezoek, zakenreizen en recreatieve reizen. Van deze drie reismotieven blijkt familiebezoek de activiteit te zijn met het grootste belang voor de kwaliteit van leven en de minste vervangbaarheid. Online communicatiemiddelen blijken onvoldoende om persoonlijk contact met familieleden te vervangen, terwijl de bestemmingen waar deze activiteit kan plaatsvinden vaak vastliggen. Het belang van zakenreizen en recreatieve reizen voor de kwaliteit van leven, evenals de vervangbaarheid van de activiteiten die met deze twee reismotieven samenhangen, verschilde tussen individuen. Vanuit het perspectief van individuen worden recreatieve reizen beschouwd als meer optioneel en op verschillende manieren vervangbaar, en gevoelig voor veranderingen in reisomstandigheden en reiskosten. Deze bevindingen vormen de conceptuele basis voor de kwantitatieve analyse die in hoofdstuk 4 van dit proefschrift wordt gepresenteerd.

Ten derde (hoofdstuk 4) analyseert het proefschrift kwantitatief de determinanten van PAA met behulp van een op nut gebaseerd modelleringskader. De empirische analyse richt zich op recreatieve vliegreizen van Nederlandse reizigers, aangezien recreatieve reizen worden beschouwd als de meest flexibele en beleidsgevoelige vorm van vliegreizen. De studie combineert een experiment waarin de aantrekkelijkheid van bestemmingen wordt beoordeeld met een stated choice-experiment dat zich richt op de keuze van vakantiebestemmingen. Latente klassen keuzemodellering en regressieanalyse worden toegepast om het relatieve belang van aantrekkelijkheid van bestemmingen en factoren gerelateerd aan gegeneraliseerde reiskosten te schatten, terwijl tegelijkertijd heterogeniteit tussen reizigers wordt meegenomen. De resultaten tonen aan dat reizigers afwegingen maken tussen de aantrekkelijkheid van bestemmingen en de gegeneraliseerde kosten van reizen. Hogere reiskosten, langere reistijden en meer vereiste voorbereidingen hebben een negatief effect op ervaren bereikbaarheid, terwijl aantrekkelijke bestemmingskenmerken deze juist positief beïnvloeden. Het belang van deze factoren verschilt echter aanzienlijk tussen reizigers, hetgeen wijst op substantiële heterogeniteit in percepties van bereikbaarheid. Sommige reizigers zijn zeer gevoelig voor reistijd of het risico op ongemak, terwijl anderen meer belang hechten aan kenmerken van bestemmingen en bereid zijn hogere reisweerstanden te accepteren om voorkeursbestemmingen te bereiken.

De bevindingen hebben tevens belangrijke implicaties voor klimaatbeleid gericht op de luchtvaart. Beleidsmaatregelen die gericht zijn op het verminderen van luchtvaartemissies via prijsinstrumenten, zoals CO_2-beprijzing, zullen waarschijnlijk invloed hebben op ervaren bereikbaarheid doordat ze de gegeneraliseerde kosten van vliegreizen verhogen. Prijsmaatregelen die momenteel gepland of geïmplementeerd zijn, hebben echter slechts een marginaal effect op de ervaren bereikbaarheid van recreatieve vliegreizen. Zowel het aandeel van luchtvaartemissies dat gecompenseerd moet worden als de meeste historische CO_2-prijzen blijken te laag om effectief gedragsverandering bij recreatieve vliegreizigers te stimuleren.

Bovendien zijn credits uit cap-and-trade-markten gebaseerd op naleving van emissieplafonds in plaats van op directe emissiereductie of emissievermijding, waardoor geen garantie bestaat voor absolute emissiereductie indien gedragsverandering uitblijft. Het proefschrift betoogt daarom dat aanzienlijk hogere koolstofprijzen noodzakelijk zijn voor effectieve gedragsbeïnvloeding binnen recreatieve vliegreizen. Beleidsmakers zouden daarom kunnen overwegen om het gebruik van CO_2-verwijderings- of emissievermijdingscredits verplicht te stellen om de volledige CO_2-emissies van recreatieve vliegreizen te compenseren. De implementatie van dergelijk beleid zou de klimaatimpact van luchtvaart verder kunnen verminderen als het wordt gecombineerd met de financiering van projecten gericht op koolstofverwijdering of emissievermijding.

De resultaten met betrekking tot ervaren bereikbaarheid laten bovendien zien dat de impact van dure koolstofcredits op de ervaren bereikbaarheid van recreatieve vliegreizen mogelijk minder ernstig is dan eerder werd aangenomen. Indien langeafstandsvliegreizen in het algemeen minder gebruikelijk worden, kan het verlies aan nut van vakanties dichter bij huis of van minder frequente vliegreizen kleiner zijn dan verwacht wanneer positionaliteit — waarbij de waarde van een goed of dienst wordt beïnvloed door het gedrag van anderen — in beschouwing wordt genomen. Met andere woorden: mensen vinden het minder erg als ze minder vaak of ver kunnen vliegen, als anderen ook minder vaak of ver vliegen. Bovendien kunnen beleidsmakers, indien via CO_2-verwijderings- of emissievermijdingscredits en gerelateerde gedragsveranderingen een absolute reductie van de klimaatimpact van de luchtvaart wordt bereikt, maatregelen overwegen om ervaren bereikbaarheid gedeeltelijk te herstellen door andere aspecten van recreatieve vliegreizen te verbeteren, zoals het verhogen van de betrouwbaarheid van vluchtschema's of het verminderen van noodzakelijke stappen bij grensoverschrijdend reizen door vereenvoudigde toeristische grensprocedures te onderhandelen met landen die veel door recreatieve reizigers worden bezocht.

Al met al draagt dit proefschrift bij aan zowel bereikbaarheidsonderzoek als beleidsdiscussies over de luchtvaart door een conceptueel en empirisch kader te ontwikkelen voor ervaren bereikbaarheid via luchtvaart. Het biedt inzichten die suggereren dat bereikbaarheid in de context van luchtvaart niet volledig kan worden begrepen op basis van uitsluitend 'objectieve' transport- en ruimtelijke indicatoren, maar ook rekening moet houden met percepties, voorkeuren en afwegingen van reizigers. Door bereikbaarheidstheorie, ervaren bereikbaarheid en op nut gebaseerde modellen te integreren, biedt het proefschrift nieuwe inzichten in de wijze waarop vliegreizigers hun bereikbaarheid van verre bestemmingen evalueren en hoe klimaatbeleid deze evaluaties kan beïnvloeden.

Chapter 1 Introduction

1.1. Background

Air transportation plays a crucial role in modern society by enabling access to activities and opportunities located at great distances that would otherwise be difficult or impossible to reach. By substantially reducing travel time and overcoming geographical barriers, aviation expands individuals' spatial reach and facilitates participation in economic, social, and recreational activities worldwide. In this sense, air transportation serves primarily as a means to an end: enabling access to desired destinations, activities and opportunities.

Despite these benefits, the air transportation sector is associated with significant environmental impacts, particularly in terms of greenhouse gas emissions. While technological advancements have improved fuel efficiency and operational performance, the overall climate impact of aviation has continued to increase due to global population growth, rising incomes and decreasing ticket prices, which have driven strong growth in air travel demand. At present, there is no technologically mature and commercially viable solution that can achieve fully climate-neutral air travel in the foreseeable future.

As a result, policy discussions have increasingly focused on market-based measures, such as carbon pricing and offsetting schemes, to mitigate aviation emissions. International bodies such as the International Civil Aviation Organization (ICAO) have introduced mechanisms to address emissions; however, these measures have often been criticized for being relatively weak and ineffective (Gössling and Humpe, 2020; Graver et al., 2020; Scheelhaase et al., 2019; Schneider and La Hoz Theuer, 2019). Most importantly, ICAO's Carbon Offsetting and Reduction Scheme for International Aviation (CORSIA) is not aligned with 1.5°C or 2°C pathways, as the effects of CORSIA, even when combined with the effects of European Union Emissions Trading Scheme (EU ETS), is estimated to result in marginal decrease in carbon emissions from aviation, and increase in climate effect from aviation emissions if non-CO_2

emissions are also considered (Larsson et al., 2019). In practice, the preservation of economic interests of states and the aviation sector has frequently taken precedence over the pursuit of ambitious climate goals. Consequently, more stringent policy measures are likely to be required to achieve absolute reductions in aviation emissions.

While the environmental necessity of such measures is widely acknowledged, their implications for air travelers remain insufficiently understood. Since air transportation is fundamentally a means of accessing opportunities, evaluating its performance requires a framework that captures both the characteristics of the transport system and the value of the activities it enables. Accessibility theory provides such a framework.

This thesis is founded in both accessibility theory and utility theory. Accessibility is generally defined as the "ease of" or "potential for" spatial interaction (Bruinsma & Rietveld, 1998). It encompasses multiple dimensions, including transportation characteristics (transport component), the spatial distribution and characteristics of opportunities (land-use component), temporal constraints (temporal component), and individual abilities and preferences (individual component), and the interaction among the components and accessibility (Geurs and van Wee, 2004). Geurs and van Wee (2004) also reveal that accessibility can be observed from different perspectives. Infrastructure-based accessibility views accessibility from the perspective of transportation infrastructure and how well it connects origin and destination locations. Location-based accessibility focuses on accessibility levels of locations considering the spatial distribution of supply and demand of desired or needed activities, and the transportation system that connects them. Person-based accessibility considers accessibility based on personal time constraints of individuals and the time window that activities and opportunities are available for access (Hägerstrand, 1970). Finally, from a utility-based accessibility perspective, accessibility is measured based on the utility that (groups of) individuals derive from access to desired or needed activities and opportunities.

In recent years, the concept of perceived accessibility has been introduced to explicitly incorporate individual perceptions, preferences, and abilities into accessibility assessments (Lättman et al., 2018; Pot et al., 2021; Negm and El-Geneidy, 2025). Perceived accessibility recognizes that accessibility is not experienced uniformly across individuals. Even for identical origin–destination pairs, perceived accessibility can vary depending on characteristics such as age, abilities, preferences, awareness of transport options, and temporal constraints (Hägerstrand, 1970; Martin et al., 2008; van Wee, 2016; Lättman et al., 2018). By incorporating these individual-level factors, perceived accessibility provides a more realistic representation of how travelers evaluate their ability to reach desired opportunities. From an accessibility research viewpoint, Pot et al. (2021) argues that individuals' inaccuracies in awareness and knowledge regarding factors that contribute to accessibility lead to differences in accessibility levels between perceived accessibility and accessibility estimated only using spatial data.

The utility-based approach to accessibility research under the random utility maximization (RUM) theory is a good fit for studies perceived accessibility by air transportation (PAA). RUM assumes that travelers make trade-offs among attributes of products or services to make rational choices that maximize utility (Train, 2009). Air travelers are motivated to make rational choices as air travel often involves high costs. Air travel is also undertaken with significantly lower frequency compared to local journeys, making rational choices more likely than choices from

habit. Using logit models on choice data, preferences of (groups of) travelers towards the contributing factors to PAA can be estimated quantitatively.

In the context of air transportation, perceived accessibility offers a promising approach for evaluating how policy measures—particularly those related to climate change—affect the actual performance of the system from the perspective of users. By analyzing PAA, policymakers can better understand how changes in costs, travel conditions, or destination characteristics influence travelers' access to long-distance activities and opportunities.

Accessibility has been extensively studied in transportation research, with the framework proposed by Geurs and van Wee (2004) identifying four key components: transport, land use, temporal, and individual components (see Chapter 2). However, applications of accessibility in the context of air transportation remain relatively limited and are characterized by a strong emphasis on objective measures based on spatial and transportation data.

Existing studies on accessibility by air transportation (AAT) primarily employ two types of approaches. Connectivity-based measures focus on network structure and the availability of connections between locations (e.g., Liao et al., 2022; Mueller, 2021), while gravity-based measures assess accessibility based on travel impedance and the distribution of opportunities (Pot & Koster, 2022; Avogadro et al., 2021). For example, Avogadro et al. (2021) applied a gravity-based approach with weighted travel time penalties to evaluate the impact of replacing short- and medium-haul flights with high-speed rail in Europe.

While these approaches provide valuable insights, they largely rely on spatial and network data and often treat traveler preferences as exogenous inputs derived from existing literature. Some studies incorporate elements related to perceived travel time, travel costs or preferences towards travel attributes in the form of generalized transport costs (Mueller and Aravazhi, 2020; Avogadro et al., 2021; Mueller, 2021). However, these studies do not aim to empirically estimate the elements related to the individual component of accessibility and only focus on elements of the individual component that are related to transport component of accessibility. The role of individual perceptions and preferences in shaping overall accessibility by air transportation remains insufficiently studied.

Several important gaps can be identified in the existing literature in relation to AAT, and accordingly PAA as well. First, although accessibility has been widely studied in local and regional contexts, long-distance AAT has received comparatively less attention. Air travel differs fundamentally from daily travel, such as commuting, in terms of frequency, decision complexity, and the nature of accessed activities. It remains unclear to what extent existing accessibility frameworks can be directly applied to air transportation, and what additional considerations are required.

Second, while moving to PAA from general AAT can provide a more behaviorally realistic framework, there is limited knowledge on how air travelers interpret accessibility and which factors contribute to PAA. The determinants of PAA have not been systematically identified or and how they form PAA has not been conceptualized.

Third, the relative importance of different determinants of PAA have not been quantitatively analyzed. Although preferences for individual air travel attributes (e.g., cost, travel time) have been studied in literature regarding air transportation, they have not been analyzed within an

integrated framework that simultaneously considers transportation characteristics, destination attractiveness, and individual perceptions.

Addressing these gaps is essential for understanding how aviation climate (and other) policies may affect air travelers. By identifying and quantifying the determinants of PAA, it becomes possible to assess how policy-induced changes—such as increased travel costs due to carbon pricing—, or changes due to non-policy related trends (such as increasing oil prices) translate into changes in accessibility and, ultimately, travel behavior.

The aim of this thesis is therefore to develop a comprehensive understanding of PAA by air transportation and to analyze how aviation climate policies may influence it.

1.2. Purpose of the thesis

This thesis addresses both a societal and a scientific challenge. From a societal perspective, there is an urgent need for effective policies to mitigate the climate impact of air transportation. Understanding how such policies affect air travelers is essential for designing measures that effectively decrease the climate impact of aviation while maintaining acceptable levels of AAT. Through a study on the determinants of PAA, this thesis provides a framework for PAA and reveals insights into how aviation climate policies may impact air travelers' (perceived) access to long-distance opportunities.

From a scientific perspective, the thesis aims to address key gaps in the literature by:

1. Characterizing accessibility research in the context of air transportation;
2. Identifying the determinants of PAA and developing a conceptual framework;
3. Quantifying the relative importance of these determinants.

1.3. Research approach

To achieve these objectives, the thesis adopts a multi-method research approach.

First, a systematic literature review is conducted to examine how accessibility has been studied in the context of air transportation, identify knowledge gaps, and characterize methodological approaches. Particular attention is given to the trade-offs between geographical scope and theoretical scope, as air transportation enables global mobility while accessibility frameworks can incorporate a wide range of dimensions.

Second, an exploratory qualitative study using focus group discussions is conducted to investigate how air travelers conceptualize accessibility. This phase identifies key determinants of PAA and explores the types of activities travelers seek to access through air travel.

Third, the importance of the identified determinants is quantified using a utility based modeling framework. This approach combines a destination attractiveness rating experiment with a stated choice experiment on vacation selection. Latent class choice modeling and regression analysis

are employed to capture heterogeneity in preferences and estimate trade-offs between destination attractiveness and travel impedance.

The empirical analysis focuses on leisure air travel by Dutch travelers, as leisure travel is considered the most flexible and responsive to policy interventions. The modeling framework adopts a utility-based perspective, assuming that travelers trade off the attractiveness of destinations against the disutility associated with travel.

1.4. Outline of the thesis

The remainder of this thesis is structured as follows.

Chapter 2 presents a literature review on accessibility in the context of air transportation, identifying key research gaps and methodological considerations. The findings from Chapter 2 led to a conclusion that a study on PAA from a utility-based perspective to accessibility research can advance knowledge regarding AAT. With insufficient knowledge in the literature regarding utility-based PAA, an explorative study was deemed necessary. Furthermore, findings from Chapter 2 revealed that a compromise between geographical and theoretical scopes is necessary for designing a feasible AAT study.

Chapter 3 reports the findings of an explorative study on PAA through the means of focus group meetings, exploring how travelers perceive accessibility and identifying its key determinants. Based on the findings in Chapter 2, the geographical scope of the origin location of travelers was set to the Netherlands. The thought processes involved in perceiving AAT as well as heterogeneity in which contributing factors contribute to PAA and how they affect PAA were observed. In particular, a clear distinction was made between PAA of trips for business and trips for leisure. The findings of Chapter 3 provide the basis for designing a feasible quantitative study relevant for analyzing the potential impact of aviation climate policies on PAA of air travelers.

Chapter 4 presents the quantitative analysis, estimating the importance of these determinants, examining heterogeneity among travelers, and analyzing the potential impacts of aviation climate policies. The theoretical scope was further defined to include variations only within vacation trips for the land-use component of accessibility, and the temporal component was fixed to a two-week summer vacation. The land-use component was limited to vacation travel as the findings of Chapter 2 indicated that vacation air travel is the most expendable and malleable, with high potential for behavioral change. The geographical scope was limited to destinations that can be reached within 15 hours of direct flight. Chapter 4 addresses a major gap in knowledge due to the lack of studies based on the utility-based approach to AAT, as identified in Chapter 2.

Finally, Chapter 5 summarizes the main findings with overarching conclusions of the thesis, discusses policy implications, and outlines directions for future research.

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Chapter 2 Long Distance Accessibility by Air Transportation: A Literature Review[1]

2.1. Introduction

The primary purpose of passenger air transportation is to facilitate access to distant opportunities that would otherwise be difficult or impossible to reach. Given this understanding, the level of accessibility that air transportation provides can be seen as a key performance measure of the air transportation system. Accessibility, in the context of transportation research, is defined generally as the 'ease of' or 'potential for' spatial interaction (Bruinsma & Rietveld, 1998). It encompasses transportation aspects, the spatial distribution of opportunities, temporal constraints, and personal constraints and preferences (Geurs & van Wee, 2004). These factors must be considered to understand the accessibility impacts of changes in air transportation, such as those arising from new climate policies (Avogadro et al., 2021) or the COVID-19 pandemic (Van Wee & Witlox, 2021). Without a thorough assessment of accessibility, policymakers in the sector run the risk of designing sub-optimal policies. Airlines or companies involved in tourism may benefit from understanding the importance of accessibility by air transport (henceforward, AAT) for some of the clients they serve.

While existing literature reviews on accessibility in general provides a solid foundation for researchers and policy makers (Handy, 1996; Bruinsma & Rietveld, 1998; Geurs & van Wee, 2004; Neutens et al., 2011; Patterson & Farber, 2015; Boisjoly & El-Geneidy, 2017), there are

[1] Sihyun Yoo, Bert van Wee & Eric Molin (2024) Long distance accessibility by air transportation: a literature review, Transport Reviews, 44:4, 811-833, DOI:10.1080/01441647.2024.2322430

distinct characteristics of air travel that are not considered in general accessibility research. These characteristics include:

- Relatively high generalized travel costs (GTC) (at least travel times and travel costs, relative to most other trips).
- Air travelers are financially, mentally, and physically prepared to accept high GTC.
- Low flexibility for itinerary changes during a trip, compared to local travel.
- High levels of uncertainty for travelers, due to low trip frequencies and trips to new destinations, and consequently limited experiences, which may influence perceived accessibility levels.
- High level of heterogeneity in terms of travelers' socio-demographic, cultural or economic backgrounds, particularly evident when comparing local and international routes.

For these reasons, researchers focusing on AAT may find that literature reviews on the general topic of accessibility have limited relevance to their work. To the best of our knowledge, a review dedicated to AAT does not yet exist. Bruinsma & Rietveld (1998) reviewed accessibility measures from existing literature for regional accessibility in Europe, covering road, rail, and air transportation. By then there were only few studies on AAT. Consequently their review is to some extent outdated and does not cover recent insights into AAT. A more recent literature review of air transportation connectivity measures by Burghouwt & Redondi (2013) includes literature dealing with AAT. However, their review adopts a strictly connectivity-based definition of accessibility and does not cover literature that approaches AAT from viewpoints other than network connectivity. As a result, the review defines accessibility mainly with respect to transportation infrastructure.

Given the state of existing literature reviews in the field, a dedicated review that encompasses a broader theoretical scope and diverse perspectives of accessibility (see below), as discussed by Geurs & van Wee (2004), is clearly needed. This study aims to fill that gap. More specifically, the added value of this paper is that we (1) reveal differences between AAT and local/regional accessibility, (2) address gaps in the literature on AAT, (3) suggest avenues for future research, (4) discuss the benefits and drawbacks of directly applying conventional accessibility measures for research on air travel, plus related options to modify conventional accessibility measures to apply them to AAT, (5) explain the relevance of AAT for policy and practices.

We document the fundamental characteristics of research in this field, including progression of research approaches (operationalization of indicators or explorative qualitative approaches), research objectives, accessibility perspectives, theoretical scopes, and the applicability of existing accessibility measures from general accessibility studies. Research approach in this paper refers to how the idea of accessibility is conceptualized for research. Some studies conceptualized accessibility based on existing measures while others approached it as a concept to be explored or as people may perceive it in their minds. To guide our analysis, the following research questions (RQs) were formulated:

A. How has AAT research approach progressed over time?
B. What are the research aims of AAT in academic research?
C. From which accessibility perspectives has AAT been studied?

D. Which theoretical scopes have been frequently or infrequently adopted in the existing literature?
E. What are the distinctive characteristics of AAT research compared to local or accessibility research and what can future researchers learn from literature in this field?
F. What are the advantages and limitations of applying existing accessibility measures to AAT?
G. What are the relations among accessibility perspectives, theoretical scopes, and measures in existing literature?
H. What research gaps exist and what avenues for future research do they present?

In the following section, the theoretical framework of accessibility and aspects of accessibility research presented by Geurs & van Wee (2004) are discussed in the context of AAT, followed by a description of methods used to collect and review literature in Section 2.3. Findings from the literature review are presented in Section 2.4, answering RQs A, B, C, and D. Section 2.5 discusses answers to RQs E, F, and G. Research gaps and avenues for future research (RQ H) are presented in Section 2.6, with concluding remarks in Section 2.7.

2.2. Accessibility theory

In this review, we analyze accessibility research in the collected literature based on the theoretical framework of Geurs & van Wee (2004), as well as two key features of accessibility research they addressed: the theoretical scope and perspectives of accessibility.

Figure 1, from the study by Geurs & van Wee (2004), illustrates the comprehensive theoretical scope of accessibility and its potentially numerous contributing factors by organizing them into four components: land-use, transport, temporal, and individual component, and the interactions among those components and accessibility. The framework is general by nature without specific attention to AAT, but apart from the characteristics of the land-use component, the framework can be applied to AAT. It is important that in the framework of general accessibility, the land-use component includes factors related to the spatial distribution of possible origin and destination locations, which can be heavily influenced by land-use policies. In the context of AAT, the influence of national land-use policies may be limited to the attractiveness of locations, characteristics of supplied opportunities, or location of airports, with very limited influence on the spatial distribution of potential origins and destinations. Although a term such as ‘location component’ may better represent this component in an air travel context, we will use the term ‘land-use component’ to ensure consistency and minimize confusion.

Figure 1 also illustrates the relationships among accessibility components and accessibility itself. In addition to direct relationships, Geurs & van Wee (2004) illustrate indirect effects of components on accessibility as well as feedback effects between components and accessibility. Indirect effects refer to the effect an accessibility component has on accessibility as a result of its effect on another component. Feedback effects refer to changes to accessibility components induced by changes in accessibility levels. Both indirect effects and feedback effects related to changes in air transportation take considerable time to materialize (Pot & Koster 2022). This may be due to the larger scale of infrastructure changes (for both transport - airports, and land use, such as developing large scale touristic destinations) associated with AAT. In addition to

the transport and land-use components, we speculate that feedback effects involving the individual component may also require longer time periods to materialize due to the lower frequency of air travel compared to local trips such as commuting or grocery shopping. In theory, this would mean that more time would pass before the average traveler has experienced any change in accessibility levels.

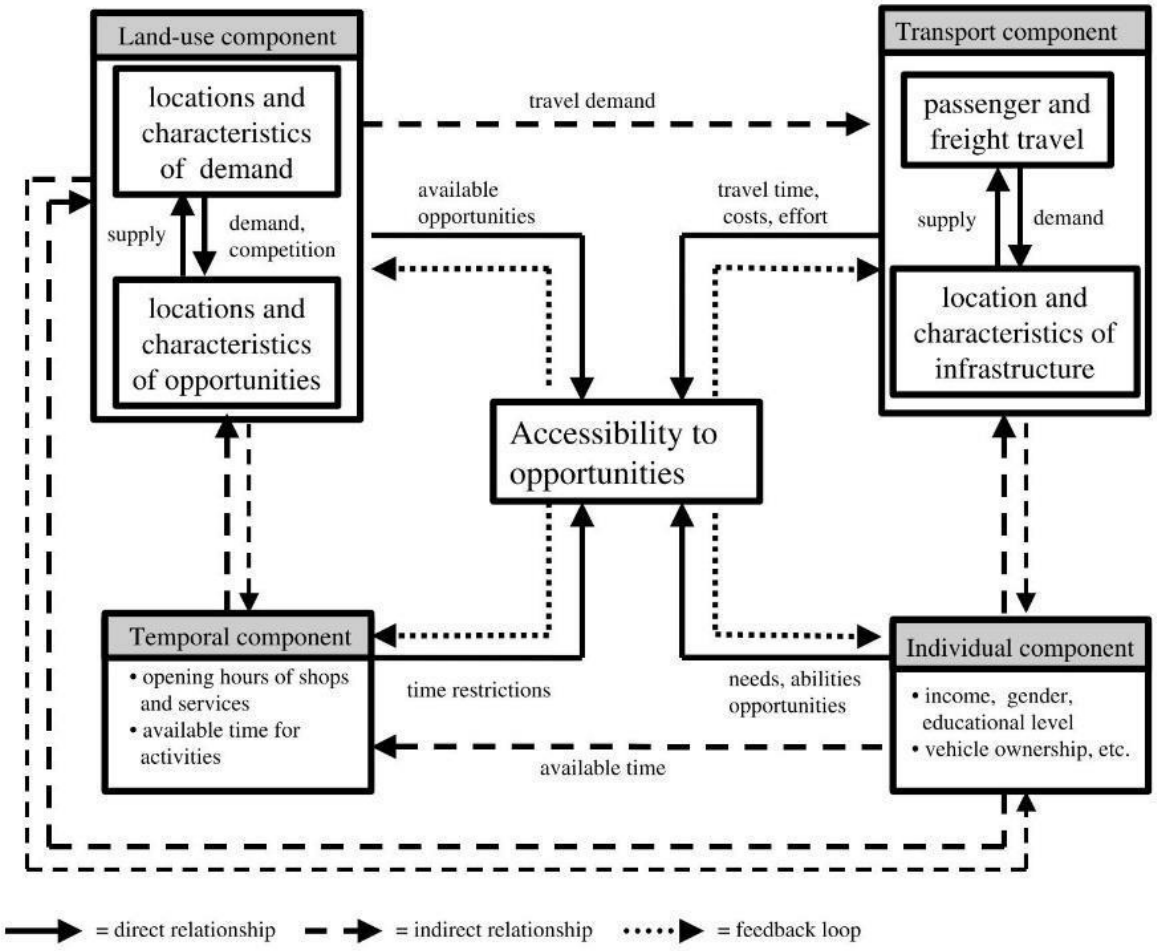

Figure 1. Relationships among accessibility and its components (Geurs & van Wee, 2004)

In addition to the accessibility components and their interactions, Geurs & van Wee (2004) introduce four perspectives of accessibility measures: infrastructure-based, location-based, person-based, and utility-based. These perspectives determine how accessibility is measured in each study. An infrastructure-based perspective evaluates accessibility based on the performance of the transport system. A location-based perspective evaluates the accessibility of a location based on the spatial distribution of the supply and demand of opportunities. A person-based perspective originates from the time geography-based accessibility measure of Hägerstrand (1970), which takes account of personal time constraints and the time windows in which opportunities are available. Finally, a utility-based perspective assesses accessibility based on the economic concept of utility and requires the use of utility-based measures, such as discrete choice modeling based on stated choice or revealed choice data. With utility being a

subjective concept, a utility-based perspective assesses accessibility as perceived by individuals or certain groups of individuals, taking account of their preferences towards factors contributing to accessibility.

2.3. Methodology

2.3.1. Literature collection scope and demarcation

In this section, we present the systematic literature search method outlined by Van Wee and Banister (2016). Our search was conducted using the online database Scopus, with filters configured to display only journal articles published in English. The collection of literature was finalized on January 19, 2023, with a total of 44 papers collected for review. The process of literature collection is depicted in Figure 2.

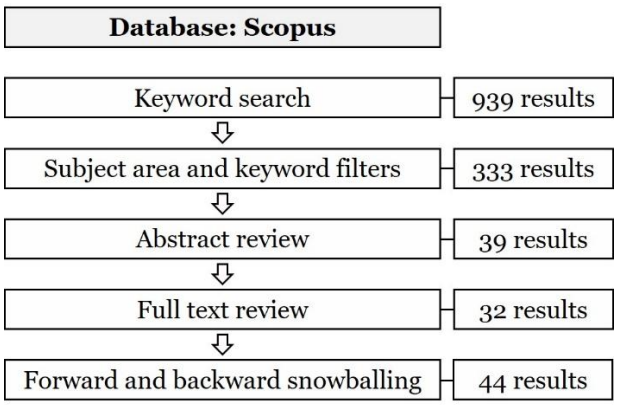

Figure 2. Literature collection process and number of results per step

The initial search was performed with a combination of primary and secondary keywords. Eight primary keywords related to air transportation were used, along with the secondary keyword ‘accessibility’. The following primary keywords were used: air transportation, air transport, aviation, airline, air travel, air traveler, air passenger, and long distance.

The boolean operator 'OR' was employed to combine the primary keywords, while 'AND' was used to incorporate the secondary keyword 'accessibility' in order to retrieve papers that included a combination of one of the primary keywords and 'accessibility'. Although early air transportation network connectivity studies often used the words ‘connectivity’ and ‘accessibility’ interchangeably, the keyword ‘connectivity’ was not used as a keyword since connectivity studies have already been reviewed (Burghouwt & Redondi, 2013), and including the large body of connectivity literature may have biased the focus and results of this review. The initial search resulted in 939 papers, of which a large number were related to health professions and nursing.

To eliminate papers in fields irrelevant to this study, ‘subject area’ filters and ‘keyword’ filters were further refined for both exclusion and inclusion in the search results. The list of subject areas and keywords selected for inclusion and exclusion in the filters, along with the final search

string, can be found in Table A1 in the Appendix. Using the filters, the results were narrowed down to 333 papers.

To further eliminate papers irrelevant to this review, the abstracts of these 333 papers were manually reviewed. Papers focused on urban accessibility or long-distance road transport were removed, along with airport access and egress studies, as these showed more commonalities with local accessibility research as opposed to long-distance accessibility. In addition, we excluded papers which focused on specific contributing factors to AAT, such as airline service quality or airport connectivity and centrality, without discussing how this relates to overall accessibility. On the other hand, early AAT studies that explicitly explained that connectivity is considered to be equivalent to AAT were included for review, because those studies show how early AAT studies approached AAT. Furthermore, we only included studies that either specified a quantitative indicator for accessibility, or explained the definition or theoretical scope of AAT adopted in the respective studies. After reviewing the abstracts, 39 papers were found to be relevant for our present study.

Finally, we reviewed the full texts of the 39 papers. Seven papers that focused specifically on air transportation network connectivity without discussing accessibility were further eliminated, resulting in 32 papers. In order to search for additional relevant papers that may have been excluded from the initial results, we then conducted a snowballing process in line with the procedure described by Van Wee and Banister (2016). Through forward and backward snowballing of the 32 papers, twelve additional relevant papers were collected, resulting in 44 papers for review. Table 1 lists these, along with their respective geographical scopes and mode(s) of transportation studied.

Table 1. Transport mode(s) included and geographical scope of collected literature

Reference	Transportation mode	Geographical scope
Toh, 1984	Air	International
Irwin & Kasarda, 1991	Air	U.S. domestic
Bruinsma & Rietveld, 1993	Air, road, rail	42 agglomerations in Europe
Chou, 1993a	Air	U.S. domestic
Chou, 1993b	Air	U.S. domestic
Shaw & Ivy, 1994	Air	U.S. domestic
Bruinsma & Rietveld, 1998	Multimodal	Europe
Bowen, 2000	Air	Southeast Asia, connected regions
Bowen, 2002	Air	Global
Macchiavelli & Vaghi, 2003	Air	Mediterranean basin region
Matthiessen, 2004	Air	Baltic Sea area
Reynolds-Feighan & McLay, 2006	Air	Global

Spiekermann & Wegener, 2006	Multimodal	Europe
Grubesic & Zook, 2007	Air	U.S. domestic
Yamaguchi, 2007	Air	Japan domestic
Hsu & Shih, 2008	Air	Global
Sellner & Nagl, 2010	Air	Austria, international
Halpern & Bråthen, 2011	Air	Norway domestic, international
Matisziw et al., 2012	Air	U.S. domestic
Redondi et al., 2012	Air	International
Banister & Givoni, 2013	HSR, multimodal	EU-27
Cao et al., 2013	Air, HSR, rail	China
Hesse et al., 2013	Air	EU-27
Mukkala & Tervo, 2013	Multimodal	Europe
Burghouwt & Redondi, 2013	Air	Europe
Redondi et al., 2013	Air	Europe, international
Borodako & Rudnicki, 2014	Air, rail	Central & East Europe, international
Sheard, 2014	Air, road	U.S. domestic
Allroggen et al., 2015	Air	Global
Cattaneo et al., 2016	Air	Italy, domestic
Vega & Reynolds-Feighan, 2016	Air, road	Ireland, international
Beria et al., 2017	Multimodal	Italy, domestic
Park & O'Kelly, 2017	Air	U.S. domestic
Dai et al., 2018	Air	Southeast Asia
Jose & Ram, 2018	Air	India, domestic
Laurino et al., 2019	Air, car, bus, rail	Italy, domestic
Sun & Lin, 2019	Air	Global
Gibbons & Wu	Air	China domestic
Mueller & Aravazhi, 2020	Air	Scandinavian region, international
Mueller, 2021	Air	Europe, U.S. domestic
Avogadro et al., 2021	Air, HSR	Europe
Bansal & Sen, 2022	Air	India

Liao et al., 2022	Air	Hong Kong, China, international
Pot & Koster, 2022	Air	Europe

2.3.2. Literature review method

This paper is a comprehensive review with thorough coverage as our aim was to construct a solid foundation for future researchers in the field. This is in line with the advice of Cooper (1988) who advise for such a review in case there are no reviews to build upon. The review focused on the aspects of accessibility research and theoretical framework introduced by Geurs and van Wee (2004). Aspects of research related to RQ A (research approach progression), B (research aims), C (accessibility perspectives), and D (theoretical scopes) were directly observed from collected literature. Based on the observations, answers to RQ E (distinctive characteristics of AAT research), F (application of accessibility measures), G (relations among accessibility perspectives, measures and theoretical scope), and H (research gaps and avenues for future research) are discussed.

Observations from the literature are listed in Table A3 in the Appendix. If a paper includes multiple accessibility perspectives or theoretical scopes, both are listed in descending order of importance, relative to the research aim or conclusions. Each paper was considered to have covered a certain accessibility component if at least one element of the accessibility component was either adopted as a variable in modeling or – in the case of qualitative studies – discussed as a contributing factor. The column 'Factors contributing to accessibility' lists the accessibility elements discussed throughout the papers, while the 'Accessibility measure' column lists the type of accessibility measures used (in bold font) and the input data for the measures.

2.4. Findings from literature review

2.4.1. Progression of AAT research approaches (RQ A)

We organized the progression of research approaches with respect to AAT into development of five major approaches. We specifically observed the progression to provide an overview of approaches that have been studied in the past, and to determine whether more recent approaches replace older approaches or add to the older approaches. After considering the combination of perspectives, measures, and theoretical scopes in categorizing research approaches, we consider categorization mainly based on measures and methods, and perspectives most suitable. This resulted in four approaches based on measures and one based on perspective of accessibility. Given the extensive variations possible in conventional measures (Spiekermann & Wegener, 2006), generalization of measures was necessary. Table 2 shows the timeline of published papers for each research approach, with approaches based on the type of measures organized into columns. The perceived accessibility approach studies, based on the perspective of accessibility rather than measures, are shown in bold italic font.

Connectivity-based approaches were the first types of approaches to be popularly used to study AAT. In early air transportation network connectivity literature, the term 'accessibility' was

often used interchangeably with 'connectivity' (Toh, 1984; Irwin & Kasarda, 1991; Chou, 1993a; Chou, 1993b; Shaw & Ivy, 1994). Early connectivity-based approaches were based on the Shimbel index, which evaluates network performance using aggregate shortest path distances between all nodes in a network (Shimbel, 1953). Principal component analysis was also used in later connectivity-based studies by Hesse et al. (2013) and Bansal and Sen (2022). The second approach to appear in the body of literature was gravity-based approaches, in which accessibility is defined by the attractiveness of opportunities, spatial distribution of potential origin and destination locations, and the available air transportation between them (Bruinsma & Rietveld, 1993). The third approached observed in literature was the qualitative research approach that explored broader scopes and details specific to AAT (Matthiessen, 2004; Halpern & Bråthen, 2011; Banister & Givoni, 2013). As for the fourth approach, we observed generic approaches that were not closely related to conventional accessibility measures. These studies approached AAT with methods from other disciplines, such as economics (Yamaguchi, 2007; Sellner & Nagl, 2010), or methods that are not derived from connectivity-based nor gravity-based measures (Redondi et al., 2013; Vega & Reynolds-Feighan, 2016; Laurino et al., 2019; Park & O'Kelly, 2017). The final and most recent approach involved the adoption of elements related to perceived accessibility (Halpern & Bråthen, 2011; Borodako & Rudnicki, 2014; Cattaneo et al., 2016; Beria et al., 2017; Laurino et al., 2019; Mueller & Aravazhi, 2020; Mueller, 2021; Avogadro et al., 2021). To summarize the developments in AAT research, AAT research started with connectivity-based approaches with gravity-based approaches being adopted after 1993. Qualitative approaches and perceived accessibility-based approaches were first adopted by Bruinsma & Rietveld (1998). From 2007 onwards, several studies utilized generic approaches.

By far the greatest number were published in the Journal of Transport Geography (11), followed by the Journal of Air Transport Management and Transport Policy with six and five articles respectively (see Table A2 of the Appendix).

Table 2. Timeline of accessibility literature publications by research approach

	Transportation network connectivity-based approaches	Gravity-based approaches	Explorative studies	Generic approaches
1984	Toh, 1984			
1991	Irwin & Kasarda, 1991			
1993	Chou, 1993a Chou, 1993b	Bruinsma & Rietveld, 1993		
1994	Shaw & Ivy, 1994			
1998			***Bruinsma & Rietveld, 1998***	
2000	Bowen, 2000			
2002	Bowen, 2002			
2003	Macchiavelli & Vaghi, 2003			
2004			Matthiessen, 2004	

2006	Reynolds-Feighan & McLay, 2006	Spiekermann & Wegener, 2006		
2007	Grubesic & Zook, 2007			Yamaguchi, 2007
2008		Hsu & Shih, 2008		
2010				Sellner & Nagl, 2010
2011			***Halpern & Brathen, 2011***	
2012	Matisziw et al., 2012 Redondi et al., 2012			
2013	Burghouwt & Redondi, 2013	Cao et al., 2013 Hesse et al., 2013	Banister & Givoni, 2013	Redondi et al., 2013 Mukkala & Tervo, 2013
2014	***Borodako &Rudnicki, 2014*** Sheard, 2014			
2015	Allroggen et al., 2015			
2016		***Cattaneo et al., 2016***		Vega & Reynolds-Feighan, 2016
2017		***Beria et al., 2017***		Park & O'Kelly, 2017 ***Laurino et al., 2019***
2018	Dai et al., 2018 Jose & Ram, 2018			
2019		Sun & Lin, 2019		
2020	***Mueller & Aravazhi, 2020***			Gibbons & Wu, 2020
2021	***Mueller, 2021***	***Avogadro et al., 2021***		
2022	Bansal & Sen, 2022 Liao et al., 2022	Bansal & Sen, 2022 Pot & Koster, 2022		

Bold italic font: studies with perceived accessibility approach

From Table 2, it is apparent that the frequency of research in the field has increased noticeably since the mid-2000s. Overall, AAT research shows a trend towards including elements of perceived accessibility. Whereas earlier studies focused on air transportation network connectivity levels, AAT research has evolved to include a broader theoretical scope by considering the individual component. This trend was even observed in recent air transportation connectivity studies (Mueller & Aravazhi, 2020; Mueller, 2021), where a broad variety of contributing factors from all four accessibility components are incorporated to model connectivity. This is noteworthy considering that network connectivity-based approaches have traditionally been heavily focused on transportation network performance as opposed to other aspects of accessibility. We speculate that advancements in information and communications

technology (ICT) have influenced the body of literature significantly, with easier access to more diverse data opening doors to new research approaches (Martín & Reggiani, 2007).

Another finding was that developments in AAT research approaches are not always linked to the adoption of more sophisticated measures. Although gravity-based approaches are relatively new and have a more sophisticated theoretical basis and broader theoretical scope than connectivity-based approaches, the latter have still been used frequently in recent publications. Moreover, publications such as those by Mueller and Aravazhi (2020) and Mueller (2021) demonstrate that connectivity-based measures can be expanded to represent accessibility more realistically by adopting elements of perceived accessibility.

The fact that the relatively simple connectivity-based measures are still being used in more recent literature supports the claim of Bowen (2002), suggesting that the Shimbel index is an intentionally simplified representation of the complex concept of accessibility with advantages for certain applications. Such simplification can be especially beneficial in the field of AAT, as geographical coverage by air transportation can be highly extensive and thus a certain level of generalization and simplification is inevitable when broadly applying accessibility measures. Overall, in terms of measures, the developments discussed above must be viewed as the application of general accessibility measures to AAT context to meet more diverse research objectives, rather than more sophisticated measures making existing ones obsolete.

2.4.2. Research aims of AAT studies (RQ B)

We identified six broad categories of research aims into which the collected literature could be categorized (see Table 3). AAT studies were performed for reasons similar to those of local accessibility studies, such as evaluating the performance of the transportation system, assessing the geographical dispersion of accessibility levels, measuring the attractiveness of destinations, and estimating the economic impact of changes in accessibility levels.

A noteworthy observation was that despite accessibility being a broad and complex concept, there are only two articles exploring the fundamental characteristics of AAT. This reveals a potential gap in fundamental knowledge specific to AAT. Examples of related knowledge gaps include insights into how the temporal component can be addressed, and the effect of relatively high GTC (at least due to the higher travel times and travel costs, relative to other trips) and activity costs, on travel behavior, and the extent to which land-use policies can influence accessibility beyond administrative borders.

Table 3. Research aims of AAT studies in collected literature

Research Aims	Literature
Study accessibility as an air transportation network performance indicator	Toh, 1984 Chou, 1993a Chou, 1993b Shaw & Ivy, 1994

	Bowen, 2000 Bowen, 2002 Hsu & Shih, 2008 Matisziw et al., 2012 Burghouwt & Redondi, 2013 Allroggen et al., 2015 Dai et al., 2018 Jose & Ram, 2018 Bansal & Sen, 2022
Assess locational accessibility levels	Bruinsma & Rietveld, 1993 Bruinsma & Rietveld, 1998 Cao et al., 2013 Redondi et al., 2013 Hesse et al., 2013 Borodako & Rudnicki, 2014 Vega & Reynolds-Feighan, 2016 Beria et al., 2017 Laurino et al., 2019 Mueller, 2021 Avogadro et al., 2021 Bansal & Sen, 2022
Examine relationships between accessibility and economic growth/regional development	Irwin & Kasarda, 1991 Matthiessen, 2004 Spiekermann & Wegener, 2006 Yamaguchi, 2007 Sellner & Nagl, 2010 Mukkala & Tervo, 2013

	Sheard, 2014 Cattaneo et al., 2016 Gibbons & Wu, 2020 Pot & Koster, 2022
Assess accessibility as airport/airline performance indicators	Reynolds-Feighan & McLay, 2006 Grubesic & Zook, 2007 Redondi et al., 2012 Park & O'Kelly, 2017 Mueller & Aravazhi, 2020 Liao et al., 2022
Study accessibility as a contributing factor to the tourism industry	Macchiavelli & Vaghi, 2003 Sun & Lin, 2019
Explore definition/concept of AAT	Halpern & Bråthen, 2011 Banister & Givoni, 2013

2.4.3. Perspectives of accessibility (RQ C)

Table 4 is a summary of the number of papers that assessed accessibility from each perspective. It shows that the infrastructure and location-based perspectives dominate the literature. It also shows that none of the reviewed AAT studies departs from the utility-based or person-based perspectives, although some studies include ingredients of those perspectives. We speculate that limited data availability and the complexity of studying heterogeneous (groups of) travelers have acted as barriers to studying AAT from utility-based perspectives. This absence of research means that there are currently limited insights as to which independent variables are likely to show significant explanatory power when all four components of accessibility are considered for utility-based measures. This is a significant gap to be filled.

In addition to the four perspectives described by Geurs and van Wee (2004), we add a new category of accessibility perspective, the 'perceived accessibility perspective', first because it is a recent approach in the AAT literature (as made explicit in section 2.4.1), and secondly because it is an perspective that increasingly receives attention in the more general accessibility literature (see, for example, Pot et al., 2021). Note that there were studies that accounted for air travelers' perceptions to at least some extent, especially in connectivity-based studies, as discussed above.

Note that the sum of the frequency of adoption of ingredients of perspectives exceeds the number of AAT studies reviewed, because majority of studies (75%) studies included

ingredients of multiple perspectives. For example, eight studies that used connectivity-based measures reported findings from both infrastructure-based and location-based perspectives by including actual cities as nodes and assessing the connectivity levels of the cities (Toh, 1984; Chou, 1993a; Chou 1993b; Bowen 2002; Macchiavelli & Vaghi, 2003; Grubesic & Zook, 2007; Borodako & Rudnicki, 2014; Mueller, 2021). Gravity-based measures can yield results from both infrastructure-based and location-based perspectives even in basic form.

Table 4. Number of papers in collected literature that assessed accessibility from each perspective

Perspective	Frequency of departing from a perspective	Frequency of adoption of ingredients of a perspective
Infrastructure-based	32	44
Location-based	12	33
Person-based	0	5
Utility-based	0	1
Perceived accessibility unrelated to person-based or utility-based perspectives	0	9

2.4.4. Theoretical scopes of accessibility (RQ D)

While an ideal study would include all components of accessibility along with their interactions as conceptualized in Figure 1, this is very difficult – if not impossible – due to data limitations and modeling complexity. Varying levels of theoretical scopes were observed in the collected literature. 17 studies had theoretical scopes covering two accessibility components and there were eleven studies each with theoretical scopes involving one and three components, while five studies included all four components.

As accessibility in the field of transportation is determined primarily by the spatial distribution of potential origin and destination locations and the transportation system that connects them, the transport and land-use components were frequently incorporated, with 44 and 32 papers including these components respectively. Factors related to the transport component were included in all literature, as the literature search was performed with keywords related to air transportation. The individual component and the temporal component were incorporated significantly less frequently than the transport and land-use components, with twelve papers including the individual component and eleven papers considering aspects related to the temporal component. In addition to the lower frequency of adoption, the level of detail of these components in the literature was found to be limited. The individual component was represented in various ways, such as adopting the value of time (often: from existing studies or reports), including penalties for transfers or standby inconveniences, or by assessing accessibility separately depending on research aims. The temporal component was only observed in the form of daily accessibility assessments (Cao et al., 2013; Hesse et al., 2013).

Interactions among accessibility components and accessibility are significantly understudied in the field; eight studies focused on two components and their interactions, while only two studies did so for three components. Feedback effects were found in the literature from papers aimed at determining the impact of changes in air transportation on regional economic growth, or the causality of effects between the two[2]. Indirect effects of accessibility components through other components were completely absent in the literature; neither quantitative assessments nor discussions regarding indirect effects in the context of AAT were found.

In the process of determining the components covered in each study, we found that some elements of air travel do not always fall under the same component across studies. For example, 'airports' were typically considered as a transport component when regarded as nodes in a network. However, airports were also considered as an element of the land-use component, while major airports were regarded as intermediate destinations with attractiveness levels determined by their connectivity levels (Vega & Reynolds-Feighan, 2016). Socio-demographic characteristics were also categorized differently depending on the research context. For example, destination GDP data were considered as an element of the land-use component, while GDP data for origin locations were considered as an element of the individual component. Similarly, Sun and Lin (2019) considered GDP per capita to be an individual component, while Pot and Koster (2022) used it to represent regional economic growth, considering it a land-use component.

2.5. Discussion

In this section, we discuss the implications that the overall observations made in section 4 has on AAT research.

2.5.1. Characteristics of AAT research in comparison with local or regional accessibility research (RQ E)

At least four important differences exist between AAT and local or regional accessibility, and related research. Firstly factors that influence accessibility can be different, and even if they are the same, they can work out differently. Among the literature reviewed for this study, the paper by Sun & Lin (2019) offers insights into the factors contributing to accessibility which are specific to AAT. For example, GDP per capita and costs at the destination, geographic characteristics of origin countries (such as island status, number of land neighbors) and diplomatic relationships between origin and destination countries are contributing factors to AAT that seldom or do not apply to local or regional accessibility. Furthermore, we speculate that the influence of factors relevant for both AAT and local or regional accessibility can differ

[2] Literature focused on the relations between economic growth and changes in air transportation did not specify whether the effects studied were feedback or indirect effects. However, we observed that descriptions of the relations in the studies assumed that changes in either the transport or land-use component would affect accessibility levels, and that the changes in accessibility levels affect the other component. Therefore, we consider such stated interactions to be feedback effects even if not explicitly stated as such.

between the two types of accessibility. For example, travel costs can be immediate deal breakers in case of AAT whereas it is more likely to be an inconvenience in case of local accessibility. The opposite may apply to travel time, which can be considered an inconvenience in long-distance AAT, but can be deal breakers in local accessibility if it exceeds feasible thresholds. These differences in factors are not only relevant by themselves for understanding the differences between AAT and local or regional accessibility, but also for research, because of the design of studies and interpretation of outcomes.

Secondly, the person-based measure needs to be adapted in case of AAT. In case of local or regional accessibility these measures are generally applied at the level of daily activity patterns. Because air travel often influences activity patterns for one or even several days, applying person based measure require a reorientation towards longer than one day activity schedules. So far the literature on AAT that applies person-based measures only include daily accessibility (Cao et al., 2013; Hesse et al., 2013).

Thirdly, local and regional gravity-based accessibility approaches ignore the costs at the destination, but these costs can be very relevant in case of AAT. In tourism research, Larsen & Guiver (2013) reveal that in the case of Danish tourists, the total holiday price is more important for travel decisions than the price of the journey. Therefore researchers are advised to pay more attention to costs at the destination, for understanding accessibility in case of AAT, than in most cases of local or regional accessibility.

Fourth, in case of local and regional accessibility, higher travel times and costs are generally considered to be undesirable, and consequently lead to a lower level of accessibility. In case of AAT, this also applies but in addition, people sometimes value remote touristic destinations because of the intrinsic utility of exploring such remote destinations (Nicolau, 2008). For example, Sun & Lin (2019) explain that a higher proportion of U.K. air travelers preferred destinations located 1000-2000km away than destinations under 1000km. This raises the question of what determinants of distance decay would be suitable in gravity-based AAT research.

2.5.2. Application of accessibility measures in an air transport context (RQ F)

Air transportation network connectivity measures: Connectivity-based measures arose from air transportation network analysis and, as such, predominantly focus on the transport component. In their simplest form, these measures employ a purely infrastructure-based perspective of accessibility. Conversely, more advanced connectivity measures incorporate elements of other accessibility components by applying weights related to air traveler preferences or the attractiveness of locations (Chou, 1993a; Chou, 1993b; Bowen, 2002; Grubesic & Zook, 2007; Borodako & Rudnicki, 2014; Mueller & Aravazhi, 2020; Mueller, 2021).

This heavy focus on the transport component (and next an infrastructure-based perspective) is a limitation in terms of scope, as connectivity-based measures can be designed with just a single component. On the other hand, as explained in section 2.4.1, the simplicity of these measures is advantageous when broad geographical coverage and applicability are required (Reynolds-Feighan & McLay, 2006). Connectivity-based measures are also adequate when the focus of

study is on the transport component only with a high level of detail. Furthermore, sourcing data can be relatively straightforward, as various organizations and private companies within the air transportation sector (i.e. airport companies, International Air Transport Association, Airports Council International, OAG Aviation) compile and manage high-quality data.

Gravity-based measures: Gravity-based measures encompass, at minimum, both the transport component and the land-use component; this provides broader theoretical coverage as compared to connectivity measures. In gravity-based measures, accessibility is determined by the attractiveness of locations and the impedance present in the transport component. The benefits of gravity-based measures are equal in case of AAT as in case of local or regional accessibility. However, adding the individual component in case of AAT is problematic because specific AAT-relevant preferences must be considered with respect to both the transportation and location components. With respect to the transport component we poorly understand the importance of GTC for different groups of travelers, for example with different income levels, which will take substantial research efforts. With respect to the land use component, the value of vacations, business trips, or visiting friends and family can vary greatly across travelers, who may even have multiple motives for a single trip (notably the combination of business and tourism), which adds to the complexity (Peeters, 2017).

In addition, expanding the geographical scope of a study would require data related to a large number of potential destinations that air transportation serves in addition to the data related to the transport component.

Utility-based measures: Despite recent trends in the field towards adopting perceived accessibility, we did not find any papers in which a utility-based measure was used to assess accessibility. This would seem to be a missed opportunity. Utility-based measures have the potential to assess perceived accessibility in a sophisticated manner compared to existing studies where the individual component has simply been adopted as weights from other studies or reports. By employing random utility theory, utility-based measures enable researchers to observe how travelers make trade-offs among attributes of their overall trips (transportation along with activities at destinations) while incorporating the influence of unobserved attributes (Train, 2009). The effect of the random component in travelers' choices is also included in the log of the denominator of the logit model, which allows for the estimation of the expected utility of the choice set while accounting for randomness in traveler behavior. Moreover, given the extreme levels of GTC in air travel, fluctuating airfare, and the fact that air travel is made less frequently, there is lower probability of habitual travel behavior, and it is more likely that people make rational trade-offs between attributes (Gärling, T., & Axhausen, 2003). This characteristic of air travel aligns well with the underlying assumptions of random utility theory. Overall, Utility-based approaches aim to derive the weights of travel attributes, taking into account sample-specific characteristics as well as the influence of unobserved variables in the form of random components (Train, 2009). Advanced utility-based measures can even be designed to explicitly assess heterogeneity.

The disadvantage of utility-based measures is that the collection of tailored data adhering to specific research purposes may be required. In addition, there is a risk of respondents overly focusing on the main variables in surveys presented by researchers when stated choice data is collected. Given the absence of precedents using utility-based measures in the context of AAT,

the current literature provides limited insight as to which variables have significant influence on AAT when both transportation and destination characteristics are considered simultaneously by (different groups of) travelers. In addition, the influence of technological, economic, or societal developments on preferences and perceptions needs to be taken into account when selecting additional attributes for a utility-based measure, beyond those considered to be important in the existing literature. Accordingly, it may be necessary for researchers to conduct separate exploratory studies prior to designing utility-based studies.

Person-based accessibility measures: No study in the collected literature fully utilized a person-based measure, taking both personal time constraints and time windows of opportunities into account. As mentioned above, long distance trips over multiple days or even weeks would last beyond daily activity patterns of individuals and operating hours of shops or service facilities. Moreover, time zone differences between origins and destinations on long-haul routes can add to this complexity, and flight departure and arrival times can heavily influence activity patterns and each traveler can have different biological time constraints when dealing with jet lag. As of now, there is little knowledge in literature that can be used as a basis for designing AAT research in which a person-based measure is broadly applied to different air travel purposes and durations. Extensive preliminary research or separate explorative studies regarding activity patterns over multiple days or weeks may be required before a broadly applicable person-based measure for AAT can be designed. Nevertheless, person-based measures add the time dimension to accessibility assessment, which can be a decisive factor in air travel decisions, but currently absent in long distance AAT studies.

2.5.3. Relations among perspectives, measures, and theoretical scopes (RQ G)

In general the perspectives from which accessibility is assessed may comprise the most fundamental aspect of research design, as these are directly linked to the research purpose, and this also applies to AAT research.

Perspectives are closely linked to measures, although by varying degrees. For example, accessibility assessment from a utility-based perspective is only possible through the use of utility-based measures, while a location-based perspective requires the use of gravity-based measures. And the space-time prism introduced by Hägerstrand (1970) plays a key role in person-based measures only. Accessibility assessment from an infrastructure-based perspective allows for the greatest flexibility in the choice of types of measures.

Theoretical scope is also linked to perspectives of accessibility. Among studies using connectivity-based measures, those with broader theoretical scopes included accessibility assessments from not only an infrastructure-based perspective, but also a location-based, and, in some cases, a perceived accessibility perspective. Gravity-based measures also sometimes included the individual component in the theoretical scope in order to assess accessibility from a perceived accessibility perspective. Altogether, we observed that a broader theoretical scope was regularly adopted to be able to assess accessibility from additional perspectives when the selection of accessibility measures was otherwise limited.

Furthermore, we observed links between theoretical scope and measures. As mentioned in section 2.5.2, connectivity-based measures can only be used with the transport component,

while gravity-based measures require the transport and land-use components at minimum. A thorough assessment involving the space-time prism measure for the person-based perspective requires a theoretical scope including all four components of accessibility. Daily accessibility measures were used to provide person-based assessments to some degree, but precise information on individuals' time availability and the time windows for opportunities in air travel context has not been studied as of yet. Finally, utility-based measures require data related to the individual, transport, and land-use components.

2.5.4. Relevance of AAT for policy and practices

Transportation or land-use policy and planning should ultimately provide easier access to long distance opportunities sought by travelers, and air transport is often the only or at least an important travel option in that cases. The benefit of advanced AAT research is that a broad scope of accessibility components are considered, potentially offering more diverse and balanced options for increasing access compared to studies that include only one component. In practice this is generally the transport component. However, there seem to be only limited options to improve accessibility via the transport component, because the air transport sector has been encouraged to operate at maximum efficiency due to high operating costs (ICAO, 2004). Thus, policymakers seeking to enhance access to opportunities are advised to focus on other accessibility components, at least the land use component. This not only is relevant for accessibility policies, but also for policies that aim to reduce the environmental impact of flying. Because options to reduce emission might be limited, at least for the coming one or two decades, there might be more options to reduce those emission via changing touristic destination than to reduce emissions per aircraft passenger kilometer. Such policies could even result in about equal levels of accessibility, with important environmental benefits.

The main aim of some of the paper reviewed was to reveal insights directly for policy and planning, example being studies focusing on remote areas in terms of access to or from other regions, or assessing relationships between regional economic development and AAT.

For industry practices, we consider that AAT research can offer two benefits. First, we speculate that perceived AAT studies may provide valuable information in lowering the effort to access opportunities by aircraft. Main barriers to air travel may depend on a variety of factors related to the individual component. Understanding of the individual component and perceived accessibility may allow air transportation and tourism industry operators to provide tailored services. Secondly, insights from AAT research may provide valuable information for demand forecasting as changes in accessibility components can be triggers for changes in travel behavior.

2.6. Avenues for future research (RQ H)

Utility-based measures for perceived AAT

Utility-based AAT studies have the potential to contribute significantly to the emerging trend of perceived AAT research. If we assume that travelers perceive accessibility based on their individual 'mental maps' (Pot et al., 2021), then improving our understanding of perceived

accessibility can also serve to further reduce the gap between accessibility measured with transportation or land-use indicators and accessibility levels perceived by travelers. One avenue for achieving this is discrete choice analysis, an effective and widely used tool which assesses utility by observing how individuals make trade-offs among attributes of products or services. As of the time of writing, studies which have utilized discrete choice analysis in the field of air transportation research have aimed to study preferences and trade-offs within the transport component (Araghi et al., 2016; Lee et al., 2016; Molin et al., 2017; Choi et al., 2019), as opposed to overall accessibility. Consequently, we only found references to travelers' preferences and trade-offs among travel attributes with respect to the transport component. The use of utility-based measures with a broader theoretical scope, including attributes related to destination characteristics, is necessary for a utility-based assessment of perceived AAT. By revealing attribute coefficients from both the transport and land-use components, utility-based measures can also provide a basis for examining differences between the way people perceive short-distance local accessibility as compared to AAT, where travel frequency is lower and the general costs of travel are relatively high.

Exploring unconventional variables and modified person-based measures for perceived AAT

For future application of utility-based measures and person-based measures, identifying contributing factors to perceived AAT through exploratory studies is essential. Beyond this, empirical studies can also be designed to explore which factors contribute to perceived AAT. Examples of such factors include the substitutability of opportunities pursued, transport mode, travel route, and travel period (Van Wee et al., 2019). These could likely be experienced very differently by different travelers; for example, the degree to which different aspects of a trip can be substituted varies depending on both the purpose and conditions of the trip and individual. The effect of ICT advancements can also contribute to the body of knowledge in this field, as ICT can potentially influence perceived accessibility with easier planning, less tedious standby times, lower language barriers, and information access at unfamiliar destinations. The impact of technological developments, changing social norms, major events and accidents (such as the COVID-19 pandemic, 9/11, and accidents involving the Boeing 737 Max 8), and the resulting feedback from accessibility to the individual component are also gaps in knowledge that have yet to be addressed.

The application of person-based measures to AAT context also opens avenues for future research. The time component for AAT cannot be incorporated in the same way as in mainstream overland person-based measures. Activity scheduling as included in time-space indicators generally apply to one day, whereas the impact of (especially: long distance) air travel on activity patterns should include multiple days. Future research could explore how travelers deal with time constraints and what this implies for time-space prisms in the case of AAT. Such research may focus on factors such as the number of annual leave days and consecutive holidays or long weekends, or how trips that cross time zones affect the space dimension in relation to travel time budgets.

Feedback effects and indirect effects

Gaps related to AAT feedback effects and indirect effects may not be easy to reduce, as panel data spanning long periods of time is needed in order to observe large-scale developments such

as fleet adjustment and the acquisition of additional aviation rights (Pot & Koster, 2022). We speculate that feedback effects and indirect effects involving the individual component, may also take longer to manifest than is the case with local accessibility, as these effects require air travelers (whose frequency of travel is comparatively low) to experience changes in accessibility levels or accessibility components. Furthermore, it may be difficult to distinguish whether certain changes in accessibility levels or components were caused by indirect effects or feedback effects, or even both.

Studies dedicated to understanding the indirect effects of accessibility components in the air transportation context have the potential to add a great deal of value to the field of study. As of yet, indirect effects on AAT have not been explored and no conclusive insights can be found in the literature. A potential example of an indirect effect in the air transport context could be a greater public concern for the climate (individual component) affecting the transport component through the act of lobbying for a decrease in air traffic, which in turn affects AAT. The magnitude of such effects, or which other indirect effects exist in AAT, may remain unknown without dedicated studies. Identifying indirect effects in AAT could shed light on latent contributing factors to accessibility and enable further quantitative assessments of such effects.

Studying the indirect effects and feedback effects in AAT provides valuable insights that cannot be revealed through studies focusing only on direct relationships between accessibility and accessibility components. Let's illustrate this point with the example of a greenhouse gas (GHG) policy which affects air travel. In this scenario, increasing travel costs by aggressively applying emissions offset costs to airfare may decrease demand (direct effect). However, one cannot assume that overall emissions would decrease by only considering the transport component. Hypothetically, if the travel time and monetary budgets of potential travelers are assumed to be constant and travelers substitute air travel for more frequent local travel, a feedback effect on the land-use component may occur by inducing further development of local tourism facilities. This will shift local emissions between touristic places, for example because a person replaces a one-month holiday trip to another continent with four one-week holidays closer to home. In this hypothetical situation, policy makers would have to assess the net effect of changes in transport-related emissions and changes in local tourism-related emissions. An example of an indirect effect: aviation emissions offset requirements, such as those implemented by the International Civil Aviation Organization's Carbon Offsetting and Reduction Scheme for International Aviation or local emissions trading schemes, could affect the individual component of environmentally conscious people who consider CO_2 emissions as a resistance factor as captured by the term 'flight shame'. The reduction in emissions will reduce that resistance factor, increasing perceived accessibility (accessibility effect). As can be seen in this hypothetical example, it is not always easy or straightforward to explore if indirect effects occur, when, for whom, and what the importance of these indirect effects for AAT is. One way to help address such effects is by selecting a factor that impacts accessibility and then exploring which factors lead to the changes in that factor. So if B is a factor leading to changes in accessibility (C), then we should attempt to determine what factors (A) cause changes in factor B. Changes in C as a result of A are indirect effects. For example, decreases in flight frequency (B) decrease accessibility (C) due to the lobbying of environmental interest groups (A).

2.7. Concluding remarks

The overall picture that emerges from our study is that the literature on AAT (and long-distance accessibility in general) is still not very mature. The topic of accessibility has a broad theoretical scope, and while there is sufficient AAT literature focusing on the transport and land-use components, the same cannot be said with regards to the individual and temporal components. This observation holds true not only with respect to the quantity of research, but also to its depth. Similarly, the majority of literature in the field employs infrastructure- or location-based perspectives to accessibility and calculates accessibility levels based on spatial data. Future research could study perceived accessibility, an area that has been receiving increased attention in recent years (see, e.g., Pot et al., 2021), with utility-based or person-based approaches. We also conclude that explorative studies regarding unconventional variables relevant to perceived AAT, as referred to above (substitute modes and opportunities, ICT related, incidents) are required in order to address related knowledge gaps. In addition, researchers can carry out explorative studies to determine suitable time frames for the application of person-based measures to AAT.

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Appendix

Table A1. Literature search filter configuration and search string

	Selected	Excluded
Subject Area Filters	Social sciences Engineering Environmental sciences Computer sciences Business, management & accounting Decision sciences Economics, econometrics and finance Mathematics Psychology Multidisciplinary	Medicine Earth and planetary sciences Arts and humanities Health professions Nursing Bio chemistry, genetics and molecular biology Physics & astronomy Chemistry Materials science Chemical engineering Immunology & microbiology Energy Pharmacology, toxicology and pharmaceutics
Keyword Filters		Road transportation Roads and streets Urban transportation Motor transportation
Search String	TITLE-ABS-KEY (("air transportation" OR "air travel" OR "air transport" OR airline OR aviation OR "long distance" OR "air traveler" OR “air passenger”) AND accessibility) AND (LIMIT-TO (SRCTYPE , "j")) AND (LIMIT-TO (SUBJAREA , "SOCI") OR LIMIT-TO (SUBJAREA , "ENGI") OR LIMIT-TO (SUBJAREA , "ENVI") OR LIMIT-TO (SUBJAREA , "COMP") OR LIMIT-TO (SUBJAREA , "BUSI") OR LIMIT-TO (SUBJAREA , "DECI") OR LIMIT-TO (SUBJAREA , "ECON") OR LIMIT-TO (SUBJAREA , "MATH") OR LIMIT-TO (SUBJAREA , "PSYC") OR LIMIT-TO (SUBJAREA , "MULT") OR EXCLUDE (SUBJAREA , "MEDI") OR EXCLUDE (SUBJAREA , "EARTH") OR EXCLUDE (SUBJAREA , "AGRI") OR EXCLUDE (SUBJAREA , "ARTS") OR EXCLUDE (SUBJAREA , "HEAL") OR EXCLUDE (SUBJAREA , "NURS") OR EXCLUDE (SUBJAREA , "BIOC") OR EXCLUDE (SUBJAREA , "PHYS") OR EXCLUDE (SUBJAREA , "CHEM") OR EXCLUDE (SUBJAREA , "MATE") OR EXCLUDE (SUBJAREA , "CENG") OR EXCLUDE (SUBJAREA , "IMMU") OR EXCLUDE (SUBJAREA , "ENER") OR EXCLUDE (SUBJAREA , "PHAR")) AND (LIMIT-TO (LANGUAGE , "English")) AND (EXCLUDE (EXACTKEYWORD , "Road Transport") OR EXCLUDE (EXACTKEYWORD , "Roads And Streets") OR EXCLUDE (EXACTKEYWORD , "Urban Transportation") OR EXCLUDE (EXACTKEYWORD , "Motor Transportation"))	

Table A2. List of journals in which the collected literature has been published

Literature	Published Journal
Chou, 1993b	Journal of Transport Geography
Shaw & Ivy, 1994	Journal of Transport Geography
Bowen, 2000	Journal of Transport Geography
Matthiessen, 2004	Journal of Transport Geography
Grubesic & Zook, 2007	Journal of Transport Geography
Halpern & Bråthen, 2011	Journal of Transport Geography
Cao et al., 2013	Journal of Transport Geography
Redondi et al., 2013	Journal of Transport Geography
Beria et al., 2017	Journal of Transport Geography
Dai et al., 2018	Journal of Transport Geography
Pot & Koster, 2022	Journal of Transport Geography
Reynolds-Feighan & McLay, 2006	Journal of Air Transport Management
Hsu & Shih, 2008	Journal of Air Transport Management
Sellner & Nagl, 2010	Journal of Air Transport Management
Matisziw et al., 2012	Journal of Air Transport Management
Redondi et al., 2012	Journal of Air Transport Management
Vega & Reynolds-Feighan, 2016	Journal of Air Transport Management
Cattaneo et al., 2016	Transport Policy
Laurino et al., 2019	Transport Policy
Avogadro et al., 2021	Transport Policy
Mueller, 2021	Transport Policy
Bansal & Sen, 2022	Transport Policy
Bruinsma & Rietveld, 1998	Environment and Planning A
Mukkala & Tervo, 2013	Environment and Planning A
Park & O'Kelly, 2017	Environment and Planning A
Yamaguchi, 2007	Transport Research Part E: Logistics and Transportation Review
Allroggen et al., 2015	Transport Research Part E: Logistics and Transportation Review
Irwin & Kasarda, 1991	American Sociological Review
Banister & Givoni, 2013	Built Environment
Bowen, 2002	Economic Geography
Hesse et al., 2013	European Transport
Jose & Ram, 2018	International Journal of Students' Research in Technology & Management
Borodako & Rudnicki, 2014	International Journal of Tourism Research
Gibbons & Wu, 2020	Journal of Economic Geography
Burghouwt & Redondi, 2013	Journal of Transport Economics and Policy
Toh, 1984	Journal of Travel Research
Sheard, 2014	Journal of Urban Economics
Liao et al., 2022	Journal of Urban Planning and Development
Spiekermann & Wegener, 2006	Scienze Regionali
Sun & Lin, 2019	Tourism Economics
Macchiavelli & Vaghi, 2003	Tourism Review
Mueller & Aravazhi, 2020	Transportation Research Part D: Transport and Environment
Chou, 1993a	Transport Planning and Technology
Bruinsma & Rietveld, 1993	Urban Studies

Table A3. Literature overview findings.

Literature	Geographical scope & *transport mode*	Perspective	Theoretical scope	(Potential) Contributing factors to accessibility discussed throughout papers	Accessibility measure/factors
Toh, 1984	International	IB	TRC	Direct connections	**Valued graph theoretic method**
	Air transportation	LB	LUC	Indirect connections	Shortest direct or indirect path distance
				Shortest path distance	
				Transport mode substitutability	
				Business operation environment of cities	
				Ethnic characteristics of air travelers on given routes	
				Fleet mix	
				Aircraft capacity	
				Freedom of flight negotiations	
				Frequency	
Irwin & Kasarda, 1991	*U.S. domestic*	IB	TRC	Centrality	**Connectivity-based measure**
	Air transportation	LB	LUC	Number of connected nodes	Number of connected nodes
			Interactions	Population density	Population density
				Physical constraints for airport facility expansion	Physical constraints for airport facility expansion
				Highway network centrality reinforcing air transport	Highway network centrality reinforcing air transport
				Telecommunications as substitute for air travel	Telecommunications as substitute for air travel
				Hub and spoke structure or airline networks	Hub and spoke structure or airline networks
				International route connectivity	International route connectivity
Bruinsma & Rietveld, 1993	42 agglomerations in Europe	LB	LUC	Population	**Gravity based measure**
	Road, rail, air	IB	TRC	Spatial distribution of agglomerations	Travel time
			TMC	Overall travel time	Frequency
			INC	Air transportation schedule	Population
				Rail and ferry schedules	
				Road network data	
				Future transport infrastructure development plans	

Chou, 1993a	U.S. domestic	IB	TRC	Shortest path distances	**Relative Shimbel index (connectivity-based measure)**
	Air transportation	LB		Airline passenger traffic data	Shortest path distance
				Airline network structure	**First-order accessibility index**
				Transfers	Shortest path distance
				Traffic flow	Traffic flow
					1 transfer
					Second-order accessibility index
					Shortest path distance
					Traffic flow
					2 transfers
Chou, 1993b	U.S. domestic	IB	TRC	Shortest path distances	**First-order accessibility index (connectivity-based measure)**
	Air transportation	LB		Airline passenger traffic	Shortest path distance
				Airline network structure	Traffic flow
				Traffic flow	1 transfer
				Transfers	**Second-order accessibility index**
					Shortest path distance
					Traffic flow
					2 transfers
Shaw & Ivy, 1994	U.S. domestic	IB	TRC	Airline network structure	**Modified Shimbel index (connectivity-based measure)**
	Air transportation			Transfers	Topological distance
					Transfers
Bruinsma & Rietveld, 1998	EU	LB	LUC	Number of connections (direct/indirect)	**Explorative study**
	Multimodal	IB	TRC	Distance	
		UB	INC	Frequency	
		PB	TMC	Reliability of transportation	
		Perceived		Travel cost	
				Travel time	
				Transport network access, egress times	
				Standby times	

				Transport cost limit	
				Travel speed	
				Mass of nodes	
				Population	
				GDP	
				Traffic volume	
				Passenger volume	
				Utility derived from accessing a node	
				Value of time	
				Inconvenience	
				Personal preferences, circumstances	
				Trip purpose	
				Distance decay	
Bowen, 2000	Southeast Asia, international	IB	TRC	Connected nodes	**Shimbel index (connectivity-based measure)**
	Air transportation			Shortest path distance	Shortest path distance
				Traffic volume	**Interregional Shimbel index**
				Geographic characteristics	Non-stop flight distances
				Number of non-stop routes	
				Air service frequencies	
				Perceived reliability of air service at a given airport	
Bowen, 2002	Global	IB	TRC	Frequency	**Shimbel index (connectivity-based measure)**
	Air transportation	LB		Shortest path distance	Number of direct flight routes
				Fare levels	
				Non-stop route connections	
				Network hub structures	
				GDP per capita	
				Population	
				City-specific attractiveness	
				Geographic characteristics	

				Diversity of connected routes	
Macchiavelli & Vaghi, 2003	Mediterranean basin region	LB	LUC	Ticket purchase routes (direct online/through tour operator packages)	**Weighted direct destination connections**
	Air transportation	IB	TRC	Non-stop route connections	Flight frequency
			TMC	Airfare	Passenger traffic volume
			Interactions	Offered seat capacity	Tourism spending of origin country
				Attractiveness of region	Origin airport passenger traffic volume
				Population	Number of tourist destinations within the country
				Tourism seasonality	
				Travel sector trade balance	
				Flight frequency	
				Tour operator holiday offers (price, quantity)	
				Tourist types (individual, tour operator offers)	
				Accommodation characteristics (price, quantity)	
				Fragmentation of transportation supply	
				Destination substitutability	
Matthiessen, 2004	Baltic Sea area	IB	TRC	Airport passenger traffic	**Explorative study**
	Air transportation	LB	LUC	Air traffic volume at airports	
			Interactions	Regional GDP	
				National GDP	
				Airline network structures	
				Geo-political characteristics	
				Market demand structure	
				Connectivity	
				Regional airport information	
				Airline alliance information	
Reynolds-Feighan & McLay, 2006	Global	IB	TRC	Passenger traffic volume of airports	**Connectivity-based measure**
	Air transportation		LUC	Supplied seating capacities	Available scheduled seats
				Supplied seat mile capacities	Distance of connected routes
				Flight distance	Airport traffic volume

					Available seat miles at airport
Spiekermann & Wegener, 2006	EU	LB	LUC	Travel time	**Gravity-based measure**
	Multimodal	IB	TRC	Travel cost	Negative exponential distance decay
			Interactions	Inconvenience of travel	Minimum travel time
				Distance	Population
				Daily accessibility	Airport access/egress
				GDP	Air route connection
				GDP per capita	State border waiting times
				Income	
				Negative exponential distance decay	
				Population	
				Airport access/egress	
				Air route connection	
				Regional employment	
				Regional labor force	
				State border waiting times	
Grubesic & Zook, 2007	U.S. domestic	IB	TRC	Transfers	**Airport connectivity**
	Air transportation	LB	TMC	Number of connected routes from airports	Transfers
				Great circle distance	Number of direct, transfer connections
				Airfare	**Flight Duration**
				Flight duration	Airport-to-airport travel times including transfer times
				Geographic distribution of accessibility levels	**Monetary cost of flight**
				Supply of itinerary	Airfare per distance traveled
Yamaguchi, 2007	Japan domestic	LB	TRC	Airfare	**Generic measure**
	Air transportation	IB	LUC	Regional GDP adjusted for public investment	Airfare
			Interactions	Passenger air transport supply	Wage-based value of time (flight time, schedule delay)
				Passenger air transport demand	Regional GDP adjusted for public investment
				Wage-based value of time (flight time, schedule delay)	Distance
				Distance	Share of air transport of a given route

				Share of air transport of a given route	Passenger air transport demand
Hsu & Shih, 2008	Global	IB	TRC	Overall air travel time (including transfers)	**Gravity-based measure**
	Air transportation	LB	LUC	Small-world network model	Shortest path overall air travel time (including transfers)
				Economic activity (represented by traffic volume)	Distance decay (shortest travel time)
					Economic activity (represented by traffic volume)
Sellner & Nagl, 2010	Austria international	IB	TRC	Air traveler volume panel data	**Generic measure**
	Air transportation	LB	LUC	Population panel data	Population and air traveler ratio
				Geo-political events	
				Airline market conditions	
				Regional economic conditions	
Halpern & Bråthen, 2011	Norway domestic, international	IB	TRC	Airport Proximity	**Explorative study (attitudinal survey)**
	Multimodal	LB	LUC	Population	Perceived importance of regional airports
		PB	INC	Road travel time to Oslo	
		Perceived		Airport infrastructure scale	
				Served routes/packages	
				Travel costs	
				Public transport access to airport	
				Timing of flights	
				Frequency of flights	
				Aircraft type	
				Travel purpose	
Matisziw et al., 2012	U.S. domestic	IB	TRC	Connectivity of hub airports	**Connectivity-based measure**
	Air transportation			Passenger miles for access to hub airports	Outbound seats per week of access hubs
Redondi et al., 2012	International	IB	TRC	Number of destinations served by airports	**Connectivity-based definition**
	Air transportation			Number of available seats at airports	Number of destinations served by airports
					Number of available seats at airports
Banister & Givoni, 2013	EU-27	IB	TRC	Travel time	**Explorative study**
	HSR, multimodal	LB	LUC	HSR network structure	
				Spatial distribution of rail network access points	

				Integration with other modes	
				HSR operating speed	
				Station area development	
				Demand characteristics	
Burghouwt & Redondi, 2013	Europe	IB	TRC	Number of direct/indirect connections	**Connectivity-based measure**
	Air transportation			Indirect connection temporal coordination	Scheduled direct/indirect connections
				Number of transfer passengers at airports	Airline alliance information for transfers
				Airfare	Date of travel
				Flight duration	Transfer standby times
				Flight frequencies	
				Number of flights	
				Transfer standby times	
				Flight distance ratio between direct/indirect flights	
				Weights for standby times and flight duration	
				Number of transfers	
				Geographical scope of air transportation network	
				Date of travel	
				Number of available seats	
Cao et al., 2013	China	LB	LUC	49 cities	**Gravity-based measure**
	HSR, air transport, conventional rail	IB	TRC	Population	GDP
		PB	TMC	GDP	Weighted average travel time
				CAAC scheduled flight data	Travel costs
				Node-to-node travel times	**Daily accessibility**
				Distance	Distance decay
				Location centrality	
Hesse et al., 2013	82 major European cities in EU27	IB	TRC	Frequency	**Combination of gravity-based indicators**
	Air transportation	LB	TMC	Regional GDP	Weighted overall air travel time
		PB	LUC	Population	Frequency

				Overall travel time	Distance decay (overall air travel time)
				Travel distance	**Daily accessibility**
				Travel costs	GDP
				Distance decay	Hypothetical optimal air travel time
				Airport capacity constraints	
				Transfers	
				Distance	
				Self-potential (utility of not traveling)	
Mukkala & Tervo, 2013	Europe	LB	LUC	Employment	**Generic**
	Multimodal	IB	TRC	Purchasing power corrected GDP	Average travel time to GDP-weighted destinations
			Interactions	Air passenger volume	
				Average travel time to GDP-weighted destinations	
Redondi et al., 2013	Europe, 40 intercontinental destinations	IB	TRC	In-vehicle time	**Generic**
	Air transportation	LB	LUC	Airport access, egress times	In-vehicle time
				Transfer waiting time	Airport access and egress times
				Population	Transfer waiting time
				Air-rail transport coordination	Population
				Airport size by passenger volume	Trip per capita
				Alternative transport modes	Passenger VOT
				Passenger VOT	
Borodako & Rudnicki, 2014	Central and East Europe, international	LB	LUC	Number of MICE events (Convention Bureau of Poland)	**Connectivity-based measure**
	Air transportation, rail	IB	TRC	Air Transfers	HSR and Air traffic volume
		Perceived	INC	HSR and air traffic volume	Available hotel beds
				Number of hotel beds	
				Total travel time on main transport mode (train and air)	
				Number of direct intercity rail connections	
				Travel purpose	

				HSR service type (couchette, sleeping cars)	
				Global recognizability of cities	
				Personal connection with professionals in a city	
				Number of hotel rooms in chain hotels/high-standard facilities	
				Cultural value of cities	
Sheard, 2014	U.S. domestic	LB	LUC	Employment per industry sector	**Connectivity-based measure**
	Air transportation	IB	TRC	Employment per metropolitan area	Airport departure traffic volume
			Interactions	Size of metropolitan area	Number of passenger departures at airports
				Population	Number of destinations served daily or more
				Local labor markets	Road transport infrastructure
				Local productivity per industry sector	Number of ports in area
				Income	
				Coast region indicator (geographical factor)	
				Ground elevation levels (geographical factor)	
				Transportation costs from producer to airport	
				Air transportation costs	
				Local transportation costs at destinations	
				Goods transported by other modes	
				PAX belly cargo capacity	
				Number of passenger departures at airports	
				Number of destination airports	
				Flight frequency	
				Airport class	
				Number of passenger departures at airports	
				Number of destinations served daily or more	
Allroggen et al., 2015	Global	IB	TRC	Connected routes of airports	**Connectivity-based measure**
	Air transportation		LUC	Frequency	Connected routes of airports
			INC	Overall air travel time	Frequency
			Interactions	Assumed layover time penalty	Overall air travel time

				Detour factor based on travel distance	Assumed layover time penalty
				Airport catchment area ground access distance decay	Detour factor based on travel distance
				Population weighted by GDP per capita	Airport catchment area ground access distance decay
					Population weighted by GDP per capita
Cattaneo et al., 2016	Italy, domestic	IB	TRC	Origin quality of life rank	**Gravity-based measure**
	Air transportation	LB	LUC	Added value per capita at origin	Quality of life rank of origin
		Perceived	INC	Self-potential of origin	Added value per capita at origin
			TMC	Attractiveness of universities at destination	Self-potential of origin
				Destination substitutability	Attractiveness of universities at destination
				Overall travel time	Destination substitutability
				Presence of LCC	Overall travel time
				Daily frequency of transportation	Presence of LCC
				Alternative paths	Daily frequency of transportation
				Socio-economic characteristics of destination area	Alternative paths
Vega & Reynolds-Feighan, 2016	Ireland, international	IB	TRC	Traffic volume of airports	**Generic measure**
	Air and road transportation	LB	LUC	Spatial distribution of accessibility	Traffic volume of airports
				Airport road access times	Airport road access times
				Number of direct connections from airports	Number of direct connections from airports
				Frequency	Frequency
Beria et al., 2017	Italy, domestic (371 zones)	IB	TRC	Population	**Gravity-based measure**
	Multimodal	LB	LUC	Number of private sector jobs	Population
		Perceived	INC	Number of public sector jobs	Number of private sector Jobs
				Distance decay	Number of public sector jobs
				GDP	Exponential decay
				Trip purpose	Road distance
				Number of hotel beds	Spatial distribution of accessibility
				Attractiveness of universities at destination	Public transportation schedule
				Administrative importance of destination	Monetary cost of transportation

				Spatial distribution of accessibility	Main transportation travel time
				Frequency	Value of time
				Travel time	Tariff perception
				Monetary cost of transportation	Waiting time
				Road distance	Access time
				Value of time	Interchange time
				Tariff perception	
				Waiting time	
				Access time	
				Interchange time	
Park & O'Kelly, 2017	U.S. domestic	IB	TRC	Average arrival passenger distance of airport	**Generic measure based on spatial interaction model**
	Air transport		LUC	Average departure passenger distance of airport	Average arrival passenger distance of airport
				Distance decay	Average departure passenger distance of airport
				Detours	Exponential distance decay
				Spatial distribution of airports	Detour in comparison with great circle distance
				Transfers	Air travel demand
				Air travel demand	
Dai et al., 2018	Southeast Asia, domestic, regional	IB	TRC	Presence of scheduled flights at airports	**Connectivity-based measure**
	Regional air transport			Number of nodes in the air transportation network	Number of connected nodes
				Path lengths	Path lengths
				Clustering of connected nodes	Clustering of connected nodes
				Presence of LCC	
				Distribution of accessibility levels	
Jose & Ram, 2018	India, domestic	IB	TRC	Airport nodes	**Connectivity-based measure**
	Air transportation			Air route connections	Airport nodes
				Airport access/egress travel time	Air route connections (direct + indirect)
				Quickest path length	Flight duration
				Shortest path length	Quickest path length
				Airport ground access/egress travel time	Shortest path length

				Standby times	Airport ground access/egress travel times
				Airport centrality	Airport ground access/egress distance
				Airport ground access/egress distance	Standby times
					Airport centrality
Laurino et al., 2019	Italy, domestic (371 zones)	IB	TRC	Presence of scheduled services at airports	**Generic measure based on transportation simulation**
	Air, car, bus, rail	LB	TMC	Access and egress times	Time spent on transportation
		Perceived	LUC	Time spent on transportation	In-vehicle value-of-time
			INC	Waiting time	Transportation fare/vehicle operating costs and toll
				Transportation fare/vehicle operating costs and toll	Toll perception
				Variety of available transport modes	Access time by public transport
				Value of waiting time	Access time by car
				Interchange penalty	Egress time by public transport
				Access and egress transport modes	Public transportation access/egress costs
				Transportation schedule	Waiting time
				Shortest path	Value of waiting time
				Population	Interchange penalty
				Spatial distribution of accessibility levels	
Sun & Lin, 2019	Global	LB	LUC	Average travel distance (inbound, outbound)	**Gravity-based measure**
	Air transportation	IB	INC	Burton's four phases of tourism participation	Tourism competitiveness index (World Economic Forum)
			TRC	Social, economic development status of origin country	Environmental performance index (Yale University)
				Geo-political characteristics	Education level of origin country
				Migrant population rate and international trade	GDP per capita of origin country
				Euclidean distance between capital cities	Purchase power parity
				Population	Percent of population over 65 years of age in origin country
				Land size	Urbanization level of origin country
				Population ages 65 and above	Number of international airports
				Urbanization level	Number of seaports
				Enabling environment	Road length

				Policy and enabling conditions	Trade value
				Infrastructure development status	Number of international flights
				Natural and cultural resources	Number of countries connected with flights
				Environmental performance index	Number of land neighbors
				Island status	Island status
				Number of land neighbor countries	Total length of land borders
				Border length with land neighbor countries	Number of visa-free countries
				Passport index (visa-free agreements)	Percent of migrants to population
				Institutional policy for cross-border movements	
				Number of international departure flights	
				Spillover effects	
				Tourism competitiveness	
				Purchasing power parity	
				Education index	
				GDP per capita	
				National development level of origin location	
				Number of countries serviced by direct flights	
				Transport capacity	
				International visitor flow	
				Air transport liberation policy	
Gibbons & Wu, 2020	China domestic	IB	LUC	Port-to-port journey time	**Generic measure**
	Air transportation	LB	TRC	Airport ground access time	Estimated minimum door-to-port journey time
			Interactions	Population	Population
				Check-in, disembark times	Check-in, disembark times
				Geographic coordinates of airports	Geographic coordinates of airports
				Airports with regular commercial flights	Airports with regular commercial flights
				Regional industrial output per industry sector	
				Regional education level	
	Scandinavian region - international	IB	TRC	In-vehicle time	**Connectivity-based measure**

Mueller & Aravazhi, 2020	*Air transportation*	Perceived	INC	Transfer waiting time	In-vehicle time
			LUC	Inconvenience of transfers	Transfer waiting time
			TMC	Number of transfers	Inconvenience of transfers
				Airfare	Number of transfers up to 2 transfers
				Schedule delay	Airfare
				Economic output of destination airport hinterland	Schedule delay
				Airline type (LCC, FSC)	Economic output of destination airport hinterland
				Travel purpose	Airline type (LCC, FSC)
				Market competition conditions	Travel purpose
				Preferences	Time penalty for self-hubbing practices
				Inconvenience of self-hubbing practices	In-vehicle value-of-time
				In-vehicle value-of-time	
Mueller, 2021	Europe, U.S. domestic EAS/PSO routes	IB	TRC	Airfare	**Connectivity-based measure**
	Air transportation	LB	INC	Surface transport cost	Airfare
		Perceived	LUC	Schedule delay	Surface travel cost
			TMC	Relative destination importance	Schedule delay
				Surface transport time	Relative destination importance
				Air travel time	Surface transport time
				Transfer waiting time	Air travel time
				Inconveniences of transfers	Transfer waiting time
				Per capita income	Inconveniences of transfers
				Economic output of destination airport hinterland	Per capita income
				Gateway airport substitutability	Economic output of destination airport hinterland
				Major airport access transport mode substitutability	
Avogadro et al., 2021	Europe	IB	TRC	Transport fares	**Gravity-based measure**
	Air transportation, HSR	LB	INC	Door-to-door travel time	Population
		Perceived	LUC	Out-of-vehicle waiting time weights	Distance
				Trip purpose	**Generalized Transport Cost**
				Population	Segment-weighted door-to-door travel time

				Distance	Door-to-door travel cost
				Interaction among transport component, individual component, and accessibility	Trip purpose
				In-cabin service quality	Traveler value of time
				Accommodation costs	
Bansal & Sen, 2022	India	IB	TRC	Air transportation network structure	**Connectivity-based measure**
	Air transportation	LB	LUC	Number of transfers	Flight frequency, daily departures
		PB	TMC	Port-to-port travel time	Airport operating hours
				Connected destinations	Connected destinations (direct/indirect)
				Flight frequencies	Maximum layover time of 4h
				GDP	Shortest path length
				Population	Quickest path length
				Distance	**Daily accessibility**
				Airport access, egress times	Time threshold
				Daily accessibility	Population
				Travel cost	GDP
				Schedule delay	**Gravity-based measure**
				Dependence of airports on other major airports	Port-to-port travel times
				Optimal travel time and minimum travel time ratio	GDP
Liao et al., 2022	Hong Kong, China, international	IB	TRC	Average flight duration	**Connectivity-based measure**
	Air transportation	LB		Domestic transfer standby times	Average flight duration
				International transfer standby times	Domestic transfer standby times
					International transfer standby times
Pot & Koster, 2022	Europe NUTS-2 region	LB	TRC	Airport passenger volume	**Gravity-based measure**
	Air transport	IB	LUC	Airport type by size and offered connectivity	Airport passenger volume
			Interactions	Economic importance of destination cities	Magnitude of opportunities
				Frequency	Airport passenger volume
				Direct connections from airport	Airport ground access/egress distance by road
				Flight duration	Assumed airport ground access/egress cost

				Airport passenger volume	Population
				Airport ground access/egress distance	Exponential decay for airport ground access
				Airport ground access/egress cost	
				Air accessibility per capita	
				Population	
				Regional GDP and airport market size	
				GDP per capita	

Abbreviations

HSR: High-speed rail

IB: Infrastructure based

LB: Location-based

PB: Person-based

UB: Utility-based

TRC: Transport component

LUC: Land-use component

INC: Individual component

TMC: Temporal component

Table A4. Accessibility perspectives, approaches and measures in the reviewed literature

Literature	Perspectives	Measures	Theoretical Scopes	Approach
Toh, 1984	IB, LB	Connectivity	TRC, LUC	Connectivity
Irwin & Kasarda, 1991	IB, LB	Connectivity	TRC, LUC	Connectivity
Bruinsma & Rietveld, 1993	LB, IB	Gravity	LUC, TRC, TMC	Gravity
Chou, 1993a	IB, LB	Connectivity	TRC	Connectivity
Chou, 1993b	IB, LB	Connectivity	TRC	Connectivity
Shaw & Ivy, 1994	IB	Connectivity	TRC	Connectivity
Bruinsma & Rietveld, 1998	LB, IB, UB, PB, Perceived	Connectivity	LUC, TRC, TMC, INC	Explorative
Bowen, 2000	IB	Connectivity	TRC	Connectivity
Bowen, 2002	IB, LB	Connectivity	TRC	Connectivity
Macchiavelli & Vaghi, 2003	LB, IB	Connectivity	LUC, TRC, TMC, interactions	Connectivity
Matthiessen, 2004	IB, LB	Explorative	TRC, LUC, interactions	Explorative
Reynolds-Feighan & McLay, 2006	IB	Connectivity	TRC, LUC	Connectivity
Spiekermann & Wegener, 2006	LB, IB	Gravity	TRC, LUC	Gravity
Grubesic & Zook, 2007	IB, LB	Connectivity	TRC, TMC	Connectivity
Yamaguchi, 2007	LB, IB	Generic	TRC, LUC, interactions	Generic
Hsu & Shih, 2008	IB	Gravity	TRC, LUC	Gravity
Sellner & Nagl, 2010	IB, LB	Generic	TRC, LUC	Generic
Halpern & Bråthen, 2011	IB, LB, PB, Perceived	Explorative	TRC, LUC, INC	Perceived, Explorative
Matisziw et al., 2012	IB	Connectivity	TRC	Connectivity
Redondi et al., 2012	IB	Connectivity	TRC	Connectivity
Banister & Givoni, 2013	IB, LB	Explorative	TRC, LUC	Explorative
Burghouwt & Redondi, 2013	IB	Connectivity	TRC	Connectivity
Cao et al., 2013	LB, IB, PB	Gravity, Person	LUC, TRC, TMC, interactions	Gravity

Hesse et al., 2013	IB, LB, PB	Gravity	TRC, TMC, LUC	Gravity
Mukkala & Tervo, 2013	LB, IB	Generic	LUC, TRC, interactions	Generic
Redondi et al., 2013	IB, LB	Generic	TRC, LUC	Generic
Borodako & Rudnicki, 2014	LB, IB, Perceived	Connectivity	LUC, TRC, INC	Perceived, Connectivity
Sheard, 2014	LB, IB	Connectivity	LUC, TRC, interactions	Connectivity
Allroggen et al., 2015	IB	Connectivity	TRC, LUC, INC, interactions	Connectivity
Cattaneo et al., 2016	IB, LB, Perceived	Gravity	TRC, LUC, INC, TMC	Perceived, Gravity
Vega & Reynolds-Feighan, 2016	IB, LB	Generic	TRC, LUC	Generic
Beria et al., 2017	IB, LB, Perceived	Gravity	TRC, LUC, INC	Perceived, Gravity
Park & O'Kelly, 2017	IB	Generic	TRC, LUC	Generic
Dai et al., 2018	IB	Connectivity	TRC	Connectivity
Jose & Ram, 2018	IB	Connectivity	TRC	Connectivity
Laurino et al., 2019	IB, LB, Perceived	Generic	TRC, TMC, LUC, INC	Perceived, Generic
Sun & Lin, 2019	LB, IB	Gravity	LUC, INC, TRC	Gravity
Gibbons & Wu, 2020	LB, IB	Generic	LUC, TRC	Generic
Mueller & Aravazhi, 2020	IB, Perceived	Connectivity	TRC, INC, LUC, TMC	Perceived, Connectivity
Mueller, 2021	IB, LB, Perceived	Connectivity	TRC, INC, LUC, TMC	Perceived, Connectivity
Avogadro et al., 2021	IB, LB, Perceived	Gravity	TRC, INC, LUC	Perceived, Gravity
Bansal & Sen, 2022	IB, LB, PB	Connectivity, Gravity	TRC, LUC, TMC	Connectivity, Gravity
Liao et al., 2022	IB, LB	Connectivity	TRC	Connectivity
Pot & Koster, 2022	LB, IB	Gravity	TRC, LUC, interactions	Gravity

Abbreviations

HSR: High-speed rail

IB: Infrastructure based

LB: Location-based

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LUC: Land-use component

INC: Individual component

TMC: Temporal component

Chapter 3 Perceived Accessibility by Air Transportation: A Focus Group Study of Potential Air Travelers in The Netherlands[3]

3.1. Introduction

Air transportation plays a crucial role in providing access to activities located at long distances (in some papers referred to as 'opportunities'). In the Netherlands, the most commonly pursued activity by air transportation is recreational activities followed by visiting friends and relatives (VFR) and business activities in 2018 (Zijlstra et al., 2018). The literature also shows that air travelers may engage in recreational activities on business trips, combining travel motives (Lichy and McLeay, 2018; Batala and Slavitt, 2024). From the perspective of (potential) air travelers, a desirable air transportation sector is one that provides high perceived levels of accessibility to such activities.

Hansen (1959:73) defined accessibility as 'the potential of opportunities for interaction,' while Geurs and van Wee (2004:128) defined it as 'the extent to which land-use and transport systems enable (groups of) individuals to reach activities or destinations by means of a (combination of) transport mode(s).' While studies on long-distance accessibility by air transportation can be found in existing literature, these studies are heavily based on spatial data involving locational and transportation characteristics (Park and O'Kelly, 2017; Dai et al., 2018; Sun and Lin, 2019)

[3] Yoo, S., Beumer, R., van Wee, B., Mouter, N., & Molin, E. (2025). Perceived accessibility by air transportation: A focus group study of potential air travelers in The Netherlands. Transportation Research Part A: Policy and Practice, 193, Article 104394. https://doi.org/10.1016/j.tra.2025.104394

with little or no consideration to travelers' perceptions related to accessibility. However, in reality, accessibility levels for travelers are determined by far more diverse contributing factors than just those related to locational and transportation characteristics (Geurs & van Wee, 2004). Disregarding contributing factors beyond locational and transportation characteristics, and ignoring perceptions of such characteristics may result in accessibility assessments that do not match accessibility levels actually perceived by travelers (Lättman et al., 2018; Pot et al., 2021). Perceived accessibility levels from the same origin and destination can vary depending on the various characteristics of (groups of) individuals, such as age and abilities (Martin et al., 2008; Ryan et al., 2016; Lättman et al., 2018), preferences (Geurs and van Wee, 2004), awareness of transportation and locational characteristics (van Wee, 2016), or individuals' temporal constraints (Hägerstrand, 1970). Van Wee (2016) and Pot et al. (2021), used the term 'calculated accessibility' (based on spatial data of the transportation and land-use system) to refer to accessibility indicators calculated based on spatial data, in contrast to perceived accessibility.

Existing literature demonstrates that perceived accessibility and calculated accessibility can yield different results in the same context of study (van der Vlugt et al., 2019). Departing from the definitions of Hansen (1959) and Geurs and van Wee (2004), we define perceived accessibility as 'the perceived ease of reaching activities or destinations by (groups of) individuals by means of a (combination of) transport mode(s), enabled by the land-use and transport systems. Research regarding perceived accessibility by air transportation (PAA) may provide insights into accessibility levels to activities located at long distances using air transportation as perceived by air travelers. Such insights can be used in policy and planning where a risk of potential negative impact of future policies on accessibility levels and equity in terms of accessibility exist. Such policies can be the result of direly needed air transportation climate policies (Willberg et al., 2024). However, as potentially numerous factors can influence perceived accessibility, measuring perceived accessibility is not an easy task. Incorporating characteristics of individuals may add complexity to research with heterogeneity in backgrounds, abilities and preferences of individuals.

The literature on long-distance accessibility by air transportation (AAT) incorporates travelers' perceptions of accessibility only to a limited extent. One reason perceived accessibility and calculated accessibility can differ is due to people's preferences regarding factors contributing to accessibility. Several papers include these preferences, albeit to a limited degree. Within the topic of AAT, the weights of travel attributes are often differentiated depending on the purpose (business or leisure) of travel (Beria et al., 2017), considering the difference in preferences for travel time and costs between business and leisure travelers. In their analysis of accessibility levels of Italian universities by university students, Cattaneo et al. (2016) included route and mode substitutability as well as presence of low-cost carriers (LCC) as contributing factors to accessibility to account for the fact that university students are more sensitive to travel costs than other types of travelers. Some studies make use of values of time (VOT) adopted from other air transportation studies or reports to account for travelers' preferences regarding travel times (Beria et al., 2017; Laurino et al., 2019; Moyano et al., 2018; Mueller and Aravazhi, 2020; Mueller, 2021; Avogadro et al., 2021). In other studies, researchers have included travelers' preferences via attribute weights and penalties to generalized transport costs (GTC), such as specific weights for in-vehicle transport times, waiting times, or transfer penalties (Gutiérrez et al., 1996; Mueller and Aravazhi, 2020; Avogadro et al., 2021; Mueller 2021). Personal time

constraints are considered to some extent in the literature by using daily accessibility measures, in which the time constraints of business travelers seeking same-day return trips are taken into account (Cao et al., 2013; Moyano et al., 2018). Mueller (2021) adopted preferences towards arrival times by including the time difference between ideal arrival times and scheduled arrival times of flights in the accessibility measure. Koster et al. (2011) and Bergantino et al. (2020) utilized choice models under the random utility theory to study airport accessibility, which is another one of multiple contributing factors to PAA.

In addition to preferences, some studies explored what motivates individuals to travel by air and individuals' circumstances in relation to perceptions regarding air travel. Specific insights relevant to the 'perceived' aspect of AAT were found in a study by Graham and Metz (2017) investigating potential reasons behind infrequent air travel for residents of the U.K., Belgium, the Netherlands and Germany. Although the study focused on travel behavior, the findings are relevant to PAA. Their dataset included socio-demographic data as well as survey responses regarding personal circumstances related to the frequency of air travel, such as type of occupation, disability and health condition, presence of children in the household, and internet access. They concluded that socio-economic status and personal circumstances contributed to non-flying rather than specific aviation factors. Halpern and Bråthen (2011) empirically studied the perceived importance of regional airports in Western and Northern Norway. The geographical context of the study was focused on Western and Northern Norway providing detailed insights into how regional airports impact the PAA of survey respondents and why access to activities by air transportation is important under specific geographic and climate conditions of the regions. They reveal that residents of more remote regions show higher frequency of domestic air travel, but significantly lower frequency of international air travel. The flight route network offered by local airports influenced the frequency of holidays, which is in contrast with the findings of Graham and Metz (2017). The major purpose of air travel was work related and visiting friends or relatives. Local airports were important for resident location and retention in remote regions. However, the survey used for the study was designed based on the opinions of experts in industry and academia, meaning that the concept and contributing factors of accessibility were primarily defined by experts rather than being based on input from travelers who perceive the notion of accessibility.

This overview of the literature shows that research regarding PAA is still in its early stages. In particular, no study was found in which the differences between PAA and local/regional perceived accessibility was investigated. AAT involves relatively high levels of GTC compared to GTC in local/regional accessibility context and uncertainty levels may be higher in AAT as frequency of air travel is often significantly lower than the frequency of local trips, and destinations may be unfamiliar, at least for leisure travelers who choose to visit destinations that they have not visited before (Yoo et al., 2024). How these differences influence perceptions has not yet been studied. Additionally, because knowledge regarding PAA is scarce in the literature, there is insufficient evidence from which future researchers can decide which accessibility measures would be suitable, or how conventional measures must be adjusted for quantitative assessment of PAA. To advance the understanding of PAA, this study aims to answer the following questions: (1) How is AAT defined by travelers in comparison to local accessibility, and what are the contributing factors to PAA? (2) How crucial are the activities accessible by air transportation to air travelers and to what extent can activities be substituted? (3) Which conventional accessibility measures are suitable for quantitative PAA research?

This study aims to answer these questions based on focus group meetings (FGMs) in the Netherlands. At the time of conducting this study, the COVID-19 pandemic had severely impacted passenger air transportation for close to twelve months, and the majority of people in the Netherlands had not flown for a considerable period of time. These circumstances allowed us to investigate the importance of flying and factors that were critical in dramatically decreasing long-distance accessibility levels by air transportation. In addition, because of the pandemic restrictions, we were forced to conduct the FGMs online. Since the meetings were led by an experienced mediator, we are able to compare this with regular face-to-face meetings and will do so in the discussion section.

In the discussion section, based on the results, we draw policy implications for equitable air transportation climate policy in terms of PAA. We focus on air transportation climate policy because results of this study may be used to enhance PAA, which can lead to increase in air travel frequency, exacerbating the already urgent issue of climate impact from the air transportation sector. The literature demonstrates that there is a correlation between the frequency of air travel and airport accessibility levels (Enzler, 2017; Kim and Mokhtarian, 2021; Mattioli et al., 2021) which contributes to PAA. Willberg et al. (2024) further emphasizes that future accessibility research should focus on measuring just accessibility in addition to considering planetary boundaries. Travel by air is not equitably distributed on both the global and national scales (Gössling and Humpe, 2020) and while the air travel tax models based on emissions from taking flights, flight frequency, or a combination of the two were found to be distributionally progressive in terms of household income (Büchs and Mattioli, 2024), they make explicit that some tax models may burden lower-income migrants, who are likely to be frequent VFR flyers due to dispersed social networks, more than other tax models. Therefore, we focus our policy implication discussions on air transportation climate policy in terms of equity of PAA, as well as PAA in general.

The next section explains the accessibility framework that underlies our study. This is followed by a description of the methodology in Section 3 and a description of the results in Section 4, where we answer research questions (1) and (2). Section 5 presents conclusions from the results, followed by discussions, in which we provide answers to research question (3).

3.2. Underlying theory of accessibility

We use the theoretical framework of Geurs & van Wee (2004) as the underlying theory of accessibility for this study, as it organizes potentially numerous contributing factors of accessibility into four components and their interactions with accessibility as shown in Figure 1, which can be applied to accessibility research in diverse contexts. The four components consist of the transport component, the land-use component, the individual component, and the temporal component. The transport component refers to contributing factors to accessibility that are related to aspects of transportation connecting the origin and potential destinations. This is closely related to the elements of friction or impedance in gravity-based accessibility frameworks. The land-use component includes elements related to the quality and spatial distribution of activities and origin locations. Although the component is named the ‘land-use component,’ the scope of the component is not limited to the spatial distribution of activities

influenced by land-use characteristics but includes all aspects of activities including quality and attractiveness of the activities. The land-use component is equivalent to the attraction of activities in gravity-based accessibility frameworks. In local or regional accessibility, land-use policies and characteristics may have a significant impact on the spatial distribution of activities and origin locations as they may designate the locations of residential areas, schools, office parks, commercial areas etc. In the context of AAT however, the influence of land-use policies is probably lower compared to local and regional accessibility, because such policies can only limitedly influence the attractiveness and spatial distribution of activities unless major leisure or business districts have been intentionally planned by national governments to attract long-distance visitors. Nevertheless, we use the term 'land-use component' throughout this study to avoid confusion in organizing the results according to the framework of Geurs and van Wee (2004). The individual component refers to characteristics of individuals that can influence accessibility, such as personal abilities and preferences. The temporal component covers elements of accessibility related to the time windows that activities are available and the time windows that individuals have to access them. The four components and accessibility interact with one another with direct or indirect relationships or feedback loops as shown by the arrows in the figure.

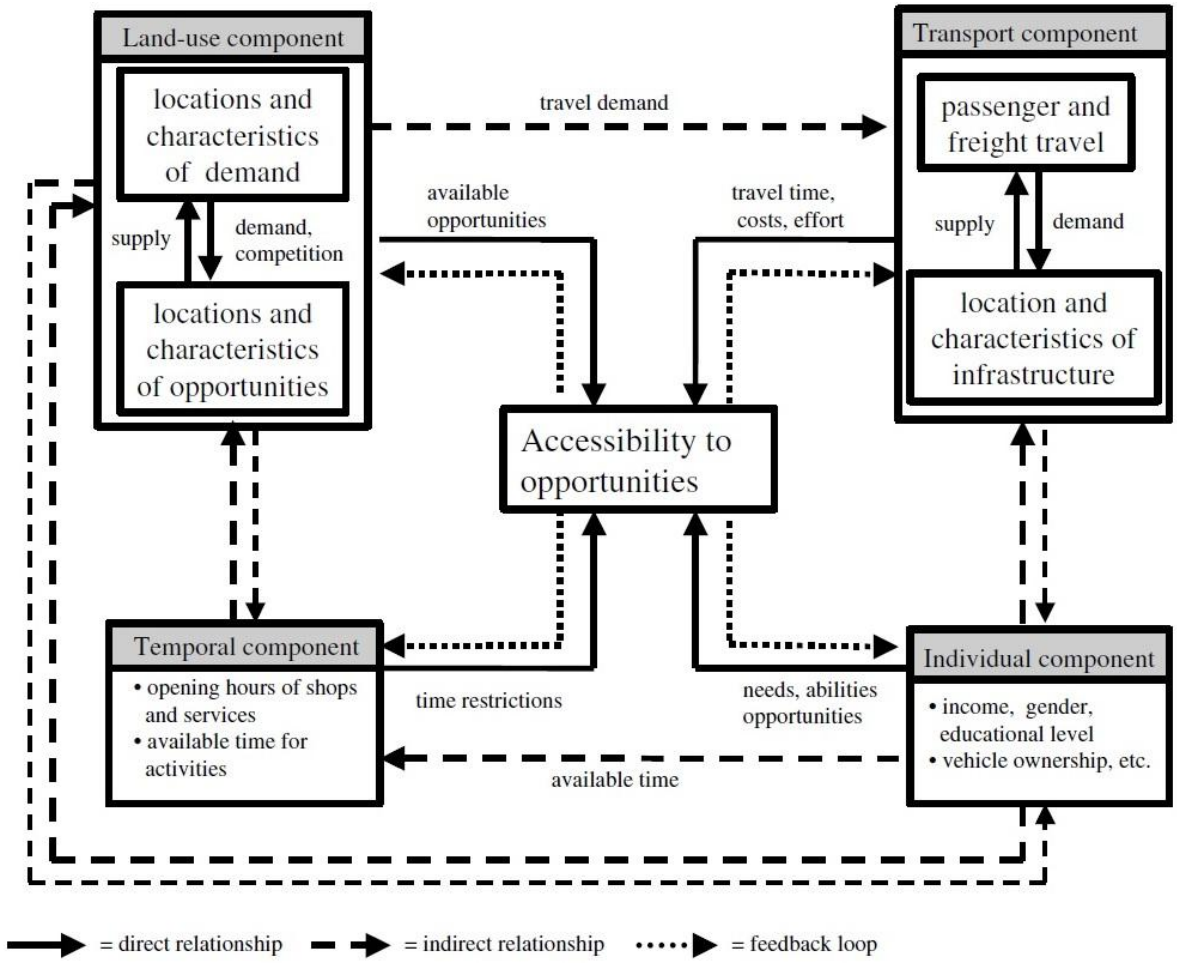


Figure 1. Theoretical framework of accessibility by Geurs and van Wee (2004)

3.3. Methodology

3.3.1. Motivation for using FGMs

FGMs is a qualitative research method where the researcher obtains data regarding opinions about a given topic by observing discussions of small groups (Basch, 1987). Two major reasons motivated the use of FGMs for this study. First, perceived accessibility can be influenced not only by personal experience or knowledge but also by experience of others (Pot et al., 2021). FGMs allows the researcher to observe the opinions of the participants in a social context where they can be influenced by the opinions and comments of others (Kitzinger, 1994). From this, researchers can also observe whether participants are in agreement or disagreement with certain opinions. Secondly, there may be differences between accessibility as conceptualized by researchers and accessibility as perceived by air travelers. Compared to one-on-one interviews, FGMs lowers the risk of the researchers revealing their perspectives regarding the subject of study to the interviewees during interactions with participants, as the interactions are not always between the researcher(s) and participant(s). FGMs has been utilized in settings where potential differences in perspectives exist between researchers and participants (Morgan, 1996). Because accessibility is a broad and complex concept, we considered that there may be differences between the frameworks of accessibility in literature and the way potential air travelers perceive accessibility.

Because we conducted the FGMs during the pandemic, the meetings were organized online. The author who performed the role of the main moderator in the meetings was experienced with FGMs prior to this study. Hence, we are able to compare the online FGMs with physical meetings and will reflect on this in Section 4.

3.3.2. Recruitment of participants

FGM participants were limited to people with Dutch nationality with air travel experience in the past five years, including at least one intercontinental destination and one within Europe. According to Airbus (2019), the Netherlands ranked 41st among 'nations and territories' in terms of average number of air trips per capita per year in 2019, with 1.7 outbound trips per capita per year. A report by Hopkinson and Cairns (2021) shows that around 58 percent of the Dutch population took flights more than once in 12 months according to 2016 data, which is the highest proportion among countries included in the report. Considering that 42 percent of the population flies less than once in 12 months and flights within Europe are much more common than intercontinental flights from Europe, the FGM participant group consisted of potential travelers with relatively diverse and recent flight experience. Such a restrictive recruitment criterion was adopted to avoid gathering information based on outdated experiences or speculation from inexperience of not having made at least one intercontinental flight.. Non-user perceptions regarding AAT are also an important aspect of PAA, but including perceptions from both participants with recent experience and those without recent experience was considered too broad of a scope for one study.

As business and leisure travel have several differences in travel circumstances, notably the fact that business trips are paid for by employers rather than the travelers, and arguably have more

limitations in freedom to choose the destination, separate meetings for the two groups were organized. In addition to the travel experience requirement mentioned above, participation in the business travel group meetings was limited to those with business travel experience within the past five years. Most participants in the group with business travel experience also had leisure travel experience, and some participants in the group with leisure travel experience had business travel experience. The term 'leisure travel' for this study includes both VFR trips and trips made to access other recreational activities. We did not limit discussions to travel experiences relevant to the travel purpose (business versus leisure) of the FGM sessions, as it was deemed natural for the participants to simultaneously consider both business and leisure trips in their ideas about AAT. Additionally, while some travelers may have combined leisure activities with business trips as suggested in the literature (Lichy and McLeay, 2018; Batala and Slavitt, 2024), we considered that motivating those participants to think of the two activities separately could hinder our observations of participants' perceptions. After exploring the results, we found that in terms of perceptions towards AAT, no substantial differences between the FGM sessions consisting of participants with business travel experience and those consisting of participants with leisure travel experience exist, apart from the fact that the groups with business travel experience were more active in expressing opinions and provided more diverse insights compared to the groups with leisure travel experience. Three FGM sessions were planned for groups with business travel experience, and another three sessions for groups with leisure travel experience. However, since we did not observe new information from the second group with leisure travel experience, we considered that we had reached saturation of information (Conradson, 2013; Guest et al., 2017) for the leisure travel experience category and canceled the planned third meeting. Hence, we organized three meetings with groups with business travel experience and two meetings with groups with leisure travel experience.

Regarding the number of participants per FGM session, the rule of thumb for the number of participants is six to ten, as stated by Morgan (1994). However, considering that online discussions may not be as natural as discussions in physical settings, we were not certain whether this number applies to online discussions. A pilot meeting with five participants (see section 2.3) lasted around 80 minutes, and we projected that six-person group meetings would require considerably more time to allow room for all participants to speak out. At the same time, we considered it important to avoid the risk of participants losing concentration from sitting in front of a screen for a long time. Eventually, we decide to recruit five participants for each meeting. However, in one of the meetings with participants with leisure travel experience, one participant failed to join, so that meeting only had four participants.

As FGMs typically does not intend to study representative samples of the population but instead strive to explore a variety of ideas, opinions and underlying reasons, we did not strive for representativeness of the Dutch population. We aimed to recruit participants with air travel experience prior to the outbreak of the COVID-19 pandemic, but not too long before, so that the air travel experiences were relatively recent. The age of participants ranged from the late 20s to mid-50s for participants with business travel experience and from early 30s to mid-50s for participants with leisure travel experience. The gender mix was seven female and eight male participants for the business travel experience group and six female and three male participants for the leisure travel experience group. Eleven people were working as employees, while four participants in the groups with business travel experience were entrepreneurs. In the groups with leisure travel experience, eight participants were working as employees, with one student

working part-time. To ensure anonymity, we replaced all participant names with fictive ones, reported provinces of residence (as opposed to cities), and replaced company names by business types. Participants were recruited through a company that provides research-related services and were offered vouchers worth EUR 45 as incentives for 1.5 hours of participation. All meetings were conducted in the Dutch language.

3.3.3. FGM session design

A pilot study was conducted before the main study to test the questions and identify unexpected difficulties in the discussions. During the pilot study, we found that the term "accessibility" tended to bias discussions towards transportation aspects in long-distance travel, with less focus on the destination or pursued activities. To mitigate this bias, an introductory video was created to remind the main study participants of all aspects of air travel, from trip planning to accessing desired activities at the destination. Additionally, in the initial questions posed during the main FGMs, "air travel" was used instead of "accessibility by air transportation," where feasible. However, the use of the term "accessibility" was inevitable in the research description for recruitment, as precise communication was necessary for ethical reasons.

The sequence of questions was organized so that participants could initially discuss their travel experiences without being influenced by the researchers' points of interest. Table 1 shows the full list of questions. After a round of introductions by the moderators and participants, the moderator asked question 2 to find out which factors contributing to PAA (both positive and negative) remained memorable to the participants from their own experiences. Questions 5 and 7 aimed to gather information on how important or desirable activities accessible by flight are for air travelers. Question 6 shared this aim as we considered that activities pursued despite pandemic measures limiting air travel could be regarded as very important or essential. At the same time, we aimed to reveal which factors related to the pandemic measures rendered distant activities inaccessible by air transportation. Question 8 specifically aimed to investigate whether health concerns were considered critical determinants of PAA after the participants became aware of the health implications of COVID-19 and the danger of infections. With question 9, the moderator asked for opinions about factors contributing to AAT found in the literature, but not mentioned by participants up to that point in the sessions. We aimed to explore whether some variables often included in the literature in this field were omitted during discussions because they were too obvious or because they were not important to the participants for some reason. This question was asked in the later part of the meetings to avoid revealing factors that are considered important in research to the participants and influencing them with this information. Questions 3 and 4 were inspired by the study by Russell and Mokhtarian (2015) to examine whether traveling by aircraft is always considered a disutility, as assumed in gravity-based accessibility studies (and many other studies making use of the concept of GTC). Question 10 aimed to reveal what fundamental differences exist between perceived long-distance AAT and perceived accessibility in a local context. Finally, questions 11 and 12 were distributed via email as a post-survey after the meetings to examine whether new information would be provided in a private setting without others listening and whether the participants had been influenced by the opinions of others.

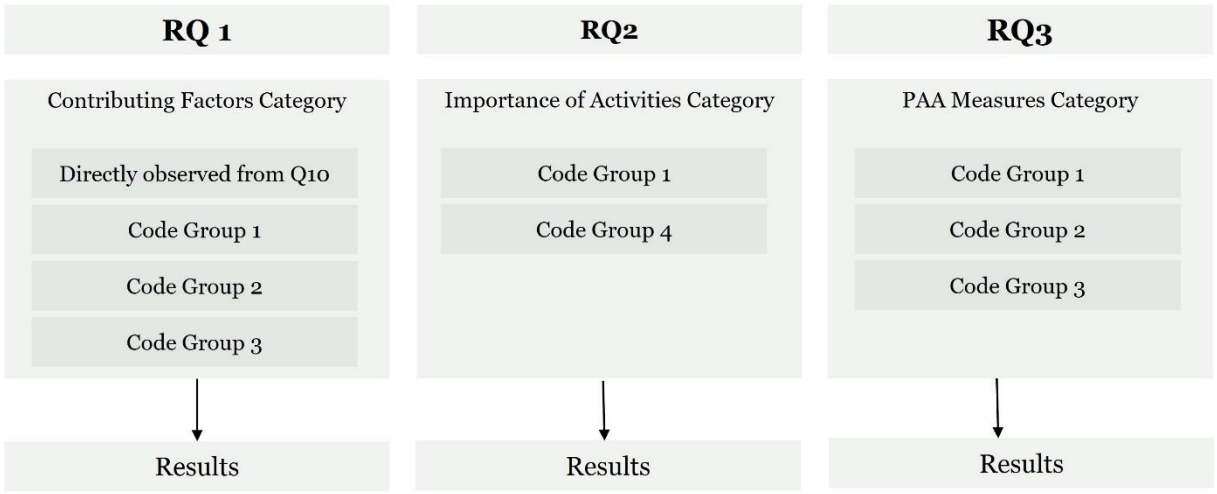
Table 1. FGM session question sequence

Questions	Planned duration
1. Please tell us your first name, main occupation and anything else you'd like to share about yourself. 2. Talk about a good travel experience and a bad travel experience you've had that involved air transportation.	20 min
3. You are to repeat the previously mentioned trips, but teleportation is available at the same cost and travel duration of taking flights. You are not conscious of the journey process and will appear at your final destination. Would you teleport or take flights, and why? (Assume the COVID-19 situation has long been resolved).	20 min
4. (For participants who chose flying over teleportation in Q3) Improvements have been made to teleportation. Now you don't have to pay and the trip is instantaneous. Would you choose teleportation over flight 5. Assuming the world returns to normal after the pandemic, what is the first trip by air that you would make, and why?	20 min
6. Have you traveled by air during the COVID-19 pandemic period or did you have to cancel plans to travel by air during this period? Why or why not?	15 min
7. Suppose that air travel is unavailable from next year onwards. What would that mean for you personally? 8. If the COVID-19 pandemic situation is not fully stopped (that is, COVID-19 will stay around like influenza), how would it affect air travel for you?	15 min
9. *(If there are air travel attributes in the checklist that have not been mentioned)* In academic research regarding long distance accessibility by air, [*unmentioned attribute*] is considered an influential factor to accessibility. Is [*attribute*] an important feature for you when traveling by air? Why or why not? 10. How would you define 'accessibility by air transportation?' What does long distance accessibility mean to you compared to local accessibility such as accessibility of grocery stores, workplace, etc.?	10 min
11. Post-survey: In planning for your next vacation (business meeting), which aspects of air travel do you feel are important to you? List as many as you would like in order of importance with your name and send it by email. Please assume that vaccination for COVID-19 has been fully distributed and therefore pandemic situation has ended. 12. Please state whether your opinion regarding accessibility by air has changed by participating in this meeting.	

3.3.4. Analysis

Video recordings of the FGM sessions were made, which were later transcribed and translated into English for analysis. The analysis was conducted using open coding based on the principles

outlined by Elo and Kyngäs (2008). Figure 2 illustrates how the code groups were categorized to address the five research questions presented in the introduction. Four groups of codes were assigned to the statements from participants. The first group of codes was based on the four components of accessibility from the accessibility framework of Geurs and van Wee (2004) explained in Section 2. The second group of codes consisted of detailed contributing factors belonging to one or more of the four accessibility components. The third group of codes was assigned based on whether a contributing factor had positive or negative contributions to PAA, whether it was a deal-breaker, and whether the statement indicated trade-off between factors contributing to PAA. For statements related to the importance of the activities pursued using air transportation, the fourth group of codes was assigned based on the substitutability of the activities and/or activity locations with those that can be accessed by other transportation modes, and the level of importance of the activities according to the expressions and reasoning in the statements of participants. Relevant code groups were then categorized to answer each research question.



Q10: How would you define accessibility by air transportation? What does long distance accessibility mean to you compared to local accessibility such as accessibility orocery stores, workplace etc.?
Code Group 1: Accessibility components from Geurs & van Wee (2004)
Code Group 2: Contributing factors to PAA mentioned by participants
Code Group 3: Positive/negative contribution to PAA, deal breakers, trade-off factors
Code Group 4: Substitutability and degree of importance of pursued activities

Figure 2. Code groups and categories for investigating research questions

Participants' definition of AAT was directly observed from participants' answers to question 10 in Table 1. The contributing factors to PAA organized into the four accessibility components of Geurs and van Wee (2004). During the analysis, we noticed that the individual component often accompanied other components in the discussions regarding aspects of air travel, as in most cases, participants had personal reasons for perceiving certain aspects of travel to be positive or negative.

For the land-use component, we specifically aimed to categorize the perceived importance of pursued activities as this is a gap in the literature. Literature indicates that the perceived importance of activities accessible by air transportation can vary across individuals (Randle et al., 2019). For this study, we categorized the importance of activities into three categories: 'essential,' 'important,' and 'substitutable,' based on responses to questions 5, 6 and 7. Table 2

illustrates how the importance of activities was categorized. Activities categorized as 'essential' were those perceived by participants as essential to avoid negative impact on their quality of life or work ('need to have'), with no feasible equivalent alternative available without the use of air transportation. 'Important' activities were those sought to enhance the quality of life or work ('nice to have'), rather than to avoid negative impact, but with no equivalent alternative accessible without the use of air transportation. Finally, 'substitutable' activities were those sought to enhance the quality of life or work, with equivalent alternatives available without the need to fly. However, during data analysis, we observed that the contribution of activities to quality of life or work and their substitutability without the use of air transportation were subjective and required interpretation. Therefore, strict categorization of the importance of activities could not be made.

Table 2. Categorization of the importance of activities

	Importance of activities		
Characteristics of activity	**Essential**	**Important**	**Substitutable**
Pursued to avoid negative impact on quality of life/work	✓		
Pursued to enhance the quality of life/work		✓	✓
Not substitutable without the use of air transportation	✓	✓	

3.4. Results

The results from the FGMs provide answers to the first and second research questions in the introduction section. Definitions of AAT by potential air travelers is presented in section 4.1. and the contributing factors to PAA observed from the FGMs are presented throughout section 4.2. Answers to the second research question are presented in section 4.2.1. where we present findings regarding the land-use component.

3.4.1. Participants' definitions of long distance accessibility by air

Participants gave various definitions of AAT, focusing on distance, travel cost, airport to airport travel times, door-to-door travel times, and the number of transfers, including those for airport access and egress. When asked about the difference between local accessibility and long-distance AAT, for the latter they frequently referred to the need for planning and organizing, and the lack of spontaneity or flexibility as a consequence, with one participant stating, "the more you have to organize, the less accessible it becomes." Low frequency of flights and limited or no options for alternative routes or transportation modes were cited to explain why there is little room from spontaneity or flexibility. One participant defined AAT as 'whether the travel time is worth it for the destination,' which aligns with the occurrence of distance decay in the

gravity framework often used in accessibility research (Bruinsma and Rietveld, 1993; Hsu and Shih, 2008; Hesse et al., 2013; Avogadro et al., 2021). Terms and statements reinforcing the importance of 'effort,' 'comfort,' and 'ease of reaching a destination' were also observed in participants' definitions of AAT, with one participant specifically explaining that flying with children influences the level of effort required for air travel. One participant explained AAT as having no limitations in terms of GTC as long as the destination is worth it. She stated that with air transportation, "if you want to get there, you'll get there… If you make a long transfer, it means it's worth it to get to your destination".

3.4.2. Contributing factors to PAA

This section presents the results, organized according to the four components of accessibility of Geurs and van Wee (2004) as explained in the introduction.

3.4.2.1. Land-use component

The land-use component in the focus group discussions mainly consisted of activities and destinations that the participants accessed or sought to access by using air transportation. Substitution of activities or destinations were also discussed, but aspects related to the spatial distribution of desired activities or destinations were not mentioned. Participants described the activities they pursue as 'business' or 'recreational' activities, 'new experiences' or 'engaging in personal or professional social activities.' The term 'destination' or names of countries and cities were also used to represent the activities that participants sought to access via air travel.

We categorized three activities, namely visiting relatives, business activities and recreational activities according to the criteria explained in section 3.4. Statements from participants with family or relatives living abroad indicated that visiting relatives is an 'essential' activity. The following are statements from participants regarding air travel for family visits:

(1) Luke: *I'm mainly worried about my girlfriend because she won't be able to see her family for a third year in a row now. It's especially unfortunate because you can't drive to Canada. I could go by boat. That would take a long time, especially with my 2 young kids.*
(2) Andy: *Not being able to see them (family) in real life would be a disaster.*
(3) Sean: *Not being able to fly at all would be dramatic. I have family abroad so flying is important to me.*
(4) Tina**:** *I'd never be able to see my sister-in-law anymore, who emigrated to Australia! I won't be able to go there, and she won't be able to visit me anymore.*
(5) Whitney (husband's family lives in Suriname): *The first big journey (after the pandemic measures are lifted) will be to Suriname of course but we will do that in a big holiday, so the summer or in December. But if it's possible we would like to go somewhere before then as well.*

Strong expressions such as 'disaster' and 'dramatic' were used. Furthermore, Luke's statement suggests that visiting relatives is important enough to ponder the idea of using a transportation mode that requires significantly more time and effort than flying. Four out of the five participants cited above stated that they would first visit their families or relatives when asked

what would be the first trip by air transportation once the COVID-19 pandemic restrictions are lifted. Furthermore, Whitney and Randy stated that online video meetings were not equivalent substitutes as 'being able to meet, touch, and hug family in person is important.' On the other hand, one participant who stated that she had been traveling to Italy every six weeks to visit a friend did not use expressions suggesting that the trip was 'essential', but mentioned that it would be the first trip once the pandemic measures are lifted. We observed that for VFR travel, visiting relatives is 'essential', but visiting friends ranges between 'essential' and 'important'.

Business activities, on the other hand, were described in manners considered to be 'essential', 'important', or 'substitutable' depending on the participant. We considered business activities 'essential' for participants who had gone on business trips despite the pandemic lockdown, experienced major shortcomings of online events as substitute means for physical events, or used strong expressions towards not being able to fly for business activities. One participant, Sonya, stated that she would change her occupation in a hypothetical situation where air travel is no longer available and her job doesn't involve business trips anymore. On the contrary, another participant, Randy, stated that although he enjoys attending conferences as part of his job, not being able to attend conferences isn't important enough for him to consider changing his job. We considered that for Sonya, business activities can be categorized somewhere between 'essential' and 'important', while Randy's comment suggested that business activities would better fit into the 'important' category. Statements such as "I've seen that it (using online means instead of flying) is doable this past year" indicated that for some participants, online activities could substitute business trips. Other options the participants mentioned for replacing business trips by flight included hiring local staff to do the job instead or acquiring equivalent business activities at locations accessible by surface transportation.

The importance of recreational activities accessible by flight also varied across participants. While we did not observe statements directly describing recreational activities as 'essential', one participant mentioned that she would prioritize flying for a holiday once the pandemic measures were lifted, despite business trips being 'high on the list' of trips she has to make. Another participant likened recreational travel to other major life decisions such as 'getting a dog or starting a family'.

Several participants explained recreational activities in a manner suitable to be categorized as 'important'. For participants who planned repeated visits to the same country or destination due to familiarity, substitute destinations may not offer the same familiarity and low level of uncertainty. Cohen (1979), explains that a certain level of familiarity in travel reduces the risk of uncertainty disturbing pleasure and relaxation. Another participant emphasized his desire to travel around the world, which may also be infeasible without taking flights. Nicolau (2008) links such tendencies with a desire to explore or seek variety. Attractiveness of a specific destinations that are accessible only by flight is also an activity that is not substitutable through use of other means of transportation. One participant expressed a desire to visit Tokyo, which is difficult to fulfill with substitute destinations, considering that cities accessible without taking a flight from the Netherlands are unlikely to offer similar experiences in terms of culture, climate or landscape.

Finally, there were statements suggesting that recreational activities accessible by air transportation are 'substitutable' through alternative activities or destinations that do not require

flying. Engaging in recreational activities other than traveling, as well as traveling by car or caravan, were mentioned in a positive manner as substitute activities to pursue in hypothetical situations where air travel is no longer available. However, attitudes towards alternative transportation modes and destinations were mixed. While one participant stated that there are enough destinations accessible by car, others showed varying degrees of dissatisfaction with the idea of not being able to fly, stating that 'great vacation' destinations accessible without flights are limited, or by using expressions such as "well, we'd just have to accept it" or "that would be annoying".

Another observation made from the transcripts was that participants showed intentions to combine business and leisure travel motives, which is in line with findings in the literature (Lichy and McLeay, 2018; Batala and Slavitt, 2024). Two business travelers directly stated that they are planning to combine business travel with leisure travel. One participant stated that she would pursue leisure activities during her upcoming business trip in the U.S., while another participant stated that after attending a conference in Australia, he would also travel to New Zealand.

3.4.2.2. Transport component

Travel time and cost

While travel times and costs were not always immediately mentioned as important contributing factors, answers to question 9 and post-survey question 11 confirmed that both are important contributing factors. We speculate that time and costs were not mentioned frequently in earlier parts of the FGM sessions because their strong influence on PAA is obvious. On the other hand, some participants confirmed that they do not pay attention to costs for business trips because the employer pays for the trips.

From the transcripts, we observed that travel time and cost were discussed in three different scopes, namely airfare and flight duration, door-to-door transit time and cost, and overall time and cost budget for the entire trip. Although the costs at destinations is part of the land-use component, we present the findings here because of the frequently mentioned links between costs at destinations and overall travel costs. The overall time and cost budget for the entire trip were discussed as deal breakers, as participants would not be able to travel unless the budgets for both are available. Several participants mentioned that overall cost is important, which is in line with the findings of Larsen and Guiver (2013). Time and cost for transportation were not mentioned as deal breakers and one participant specifically revealed intentions to trade-off between the two costs by stating that she would consider a transfer route to save money and spend more at the destination. Participants also expected trade-offs between airfare and service levels, using expressions such as "you get what you paid for". One participant also showed intentions for trade-off behavior between airfare and departure time, stating that she would depart very early or very late if the tickets were cheaper.

Time and costs for transit were both considered as disutility in travel, and thus increase the level of impedance in PAA. Flight duration was particularly described as a disutility by those who stated that they cannot sleep on flights. Some participants mentioned that flights with enough time to sleep and rest are easier to handle than short flights. Similar observations were made in

a study by Lyons et al. (2007) regarding the time use of rail passengers in Great Britain, where sleeping or snoozing during transit made the travel time worthwhile for some travelers. As for costs, participants who often travel with multiple companions stated that small differences in airfare also matter because they add up to become large cost differences, supporting the findings of Hsieh et al. (1993). Attitudes towards airport access costs were heterogeneous, with some saying that it is important and others saying it doesn't matter.

Delays, cancellation and uncertainties in transportation

Discussions regarding delays and flight cancellations were dominant in all FGMs when participants were asked about their worst air travel experiences. Although this paper is not focused on quantitative analysis, we suspect that flight delays and cancellations are significant contributing factors to PAA because in four out of five FGMs, participants first mentioned these aspects. We do not believe that delays and cancellations being mentioned by the first participant to respond to question 2 completely directed other participants to focus on these aspects, as there were also participants who mentioned other aspects of air travel to have been decisive in creating the worst experience, such as bad mood in cabins, illness of a travel companion, mishandled baggage, or unfriendly staff. Delays and cancellations were mentioned as the reasons for worst experiences even by participants who stated that they were compensated adequately. For some participants, delays lead to missed connecting flights or arrivals at times when no public transport service was available for egress. However, there was also one participant who stated, "I've flown a lot, so I'm pretty used to delays and other unpleasant events. I've learned to accept it. I'm not really bothered by it".

Uncertainty that followed or accompanied delays or cancellations was also discussed as an influential contributing factor to worst air travel experiences, although with more heterogeneity in valuations compared to delays or cancellations themselves. Lack of transparency in communications or misinformation from airlines regarding delays or cancellations were often stated to have escalated bad situations. Moreover, some participants stated that they do not use intermediary air ticket booking services or agents, stating that bookings are 'unreliable,' 'uncertain' and communication with airlines is 'annoying' during unforeseen delays or cancellations, as indirect communication with the airline through the booking agents is necessary in some cases. However, different opinions were observed regarding the effect of transparent communications during delays or cancellations. While one participant stated, "if there is a delay and they tell me why, I can live with that. But when they leave me in the dark I get quite irritated", others stated that transparent communications do not make the situation better. Overall, the results suggest that routes with frequent schedule disruptions, or destinations served only by airlines with frequent schedule disruptions and inadequate handling of such situations, may be perceived to have lower accessibility by some travelers.

Uncertainties unrelated to delay situations or cancellations were also cited as significant negative contributing factors. As the main reasons for not planning trips by air during the pandemic period, some participants mentioned uncertainties regarding changes in disease control policies at state border entries, successfully obtaining negative COVID-19 test results close to flight dates, or the possibility of insurance claims for pandemic related travel disturbances. Several participants explicitly stated that they wouldn't consider COVID-19 a

problem at all in air travel decisions when asked how COVID-19 would affect their travel behavior if it became similar to the common flu.

Behavior and mood of other people, personalized service and human touch in transportation

The human touch during air travel was discussed as an important aspect by some participants. "Unfriendly staff" was frequently mentioned as a contributing factor to worst experiences, while "friendly staff" was often mentioned in discussions about best experiences. Participants used expressions such as "you're treated like cattle," and "I get the feeling that I'm just a number to them" in describing lack of human touch. Airline personnel giving priority to passengers of other flights during delay situations, and a flight attendant's refusal to provide a blanket while a participant was ill on the flight were mentioned as worst experiences. Another participant whose travel companion had a broken seat in the cabin, stated that the fact that her group had to go through 'a bit of drama' to have the travel companion relocated 'wasn't nice,' despite an upgrade to business class.

On the other hand, good personalized services and being given priority were mentioned by some participants during their discussions regarding their best air travel experiences. In some cases, experiences described as 'personalized services' explained during best air travel experience discussions were merely standard practices of airlines, such as being given priority due to having very young or very old travel companions or flying business class. Other participants shared experiences about more unusual human touches such as a flight attendant offering interesting conversation or pilots offering a cockpit tour to children. One participant described the captain's decision to take votes from passengers to decide whether to divert or not due to toilet malfunctions in the cabin during flight as 'funny,' even though it was part of her worst air travel experience. Although unrelated to his best travel experience, one participant mentioned being given priority and personalized service due to accumulated air miles with a certain carrier as a positive contributing factor to air travel. Discussion regarding service standards was also extended to the land-use component, with one participant stating that he found some countries to have more service-oriented service industries than others.

The influence of behavior of other people extended beyond behavior of airline personnel. During discussions of worst air travel experiences, three participants mentioned crowded and noisy cabin situations and a generally 'grumpy' mood inside the cabin. Conversely, positive behavior of other passengers was mentioned to have alleviated a frustrating situation for one participant during a 17 hour delay. She stated, "passengers started taking care of each other, sharing their food and foreign currency! That was nice to see." Another participant also stated that she sometimes finds it 'nice' to fly because there are 'interesting passengers to talk to.' Social traditions with travel companions during the journey was also described as a positive aspect of traveling by flight. One participant stated "at Schiphol, we drink the first beer together, and then another one on the flight. That gives me a really nice holiday feeling!", while another participant stated that her children enjoy eating at McDonalds at Schiphol airport before taking flights.

The results show that behavior and mood of employees of transportation service providers or other sharing the flight experience can influence the level of impedance in PAA. The former can be controlled by transportation service providers to some extent to lower the level of

impedance in PAA to long distance destinations. Training airline or airport staff to create a more pleasant atmosphere during flight trips (at airports or in cabin) may to some extent influence the latter to lower the journey impedance.

Airline

Names of airlines were often spontaneously mentioned in responses regarding both the best and worst air travel experiences. While some experiences were related to operational practices directly controlled by airlines, such as in-flight service arrangements, communication channels, or airline-specific safety procedures, there were also instances where the responsible party for good or bad experiences was vague, such as experiences with mishandled baggage or delays, which could have been caused by mismanagement from either the airport or the airline. Nevertheless, it was frequently observed that participants associated service levels and schedule reliability with specific airlines. One participant stated that the 'availability of preferred airline' is an important contributing factor to AAT, and another participant went as far as to state that due to a bad in-flight experience with a certain airline, he will never fly with them again.

In-cabin experience

In the responses to the post-survey, several participants included in-cabin seating comfort as an important contributing factor to air travel experience. One participant specifically explained that she pays attention to aircraft type when flying business class because older aircraft do not have seats that fold flat into beds in business class. While most participants described business class travel experience as positive, and even more desirable than teleportation for some, one participant stated that even the space given in business class is not enough to feel comfortable. As another positive aspect of in-cabin experience, being 'cut off from communications, your work, your family' was mentioned as a 'really nice' aspect as it provides 'time for yourself.' The 'experience of flying' was also mentioned to be a desirable aspect of in-cabin experience. Several participants mentioned good food and beverage catering in the cabin as contributing factors to their best air travel experiences. One participant stated that she 'does not enjoy airplane food' and prefers to eat at the airport before taking flights. Another participant, who used the expression 'fantastic in terms of food' in describing in-cabin catering during his best travel experience, also mentioned that he would prefer to skip the journey by flight despite missing good catering when asked whether he would use teleportation instead of flying if it was available. Low pressure within the cabin, tedious views outside the windows, being seated near toilets, and not being able to step outside for a long period (in contrast to train journeys) were also mentioned as negative aspects of in-cabin experience. Overall, results show that certain aspects of in-cabin experience increase the journey impedance while there are also aspects that lower the impedance, although the influences were heterogeneous across participants.

Transfers

Transfers were generally described as a factor that increases impedance in PAA. Some participants stated that they make trade-offs between transfers and airfare. Two participants mentioned that the price difference between a direct flight and a transfer flight must be big enough to consider taking a transfer route. One of the two participants stated that she filters out tickets with two or more transfers when booking flights, suggesting that number of transfers can become deal breakers when choosing routes. Another passenger stated that she considers

transfer routes only when she can 'afford to be tired' upon arrival at the destination. The attractiveness of transfer airports was another factor stated to be important in considering transfer routes. Dubai, Singapore, Hong Kong and Bonaire were cities explained to have attractive activities or convenient facilities during transfer times or layovers. In particular, one participant mentioned that shower facilities at airports are important for him. Another participant confirmed that sometimes he arranges self-transfers and takes transfer flights from an airport other than the one where he landed, and therefore airport locations are important.

In terms of transfer time, some participants stated that they prefer the shortest transfer time, with one participant specifically mentioning that she does not take routes with transfer times of over six hours. There were also several participants who stated that they prefer transfer times long enough to 'explore' the city or surroundings of the transfer airport or layovers for a 'mini vacation,' rather than transfer times that require them to wait in the airport. Those that stated to prefer long transfer times mentioned that the attractiveness of the city or surroundings of the airport is important in deciding whether or not to take tours during transfer or layover times. One participant stated that she intentionally booked a flight with a layover in Bonaire to enjoy the island.

Characteristics of airports

There were also statements describing the importance of airport facilities and airport characteristics unrelated to transfers. In general, having to arrive early at airports to wait in long queues for check-in, security screening, border control, and being required to walk long distances to gates at large airports were discussed as inconveniences. Some participants specifically stated that they prefer smaller airports because they are 'easier to navigate,' 'relaxed,' and do not have to wait in long queues. One participant stated specifically that the availability of advanced check-in is important. Another participant described the experience of going through security screening in the U.S. as 'extreme.' Airport access and egress were also considered important by some participants, stating that the availability of public transportation access to the departure airport is important. Another participant stated that availability of egress transportation from the arrival airport to the accommodation location is important. In terms of airport facilities, some participants stated it is not important at all, while others stated that food and beverage stores, shops, and places to work while waiting for flights are important. Results show that various characteristics of airports contribute to the resistance of flights and therefore to PAA with some aspects being specific to certain airports, and others being generally applicable (not airport-specific).

Baggage

Mishandled baggage and limitations on baggage were mentioned as inconveniences of air travel. For one participant, the experience of baggage arriving a week later than him at the destination contributed to his worst air travel experience. For another participant, strict baggage weight and size limitations are a 'real problem' for his hobby of climbing, as he cannot bring along all of the required equipment. Baggage size limitations were also mentioned as an inconvenience by another participant who explained that traveling with a pram is 'tough' because oversized baggage is always the last to arrive at baggage claim. Note that mishandled baggage is route or

airline specific, whereas size or weight limitations for exceptional goods, like bicycles or prams, which are considered oversized luggage by all airlines.

3.4.2.3. Individual component

Attitudes towards planning and organizing

An interesting observation from the focus group discussions was that the participants used the terms 'planning' and 'organizing'[4] with distinction. While 'planning' was used when describing the process of selecting activities, destinations and flights, 'organizing' was mostly used when describing the process of making preparations necessary for the door-to-door journey. In general, 'organizing' was used with (slightly) negative tone, with participants saying it is a 'hassle' or "the more you have to organize, the less accessible it becomes". As explained in section 4.1, the need to organize was stated as a reason why there is no room for spontaneity or flexibility in air travel. One participant stated that even a spontaneous trip by air transportation using a last-minute flight deal is 'still an undertaking.' The disutility of organizing was also mentioned in discussions regarding air travel during the COVID-19 period. Multiple COVID-19 tests being required by airlines and disease control authorities before flights were stated to lower AAT. One participant stated that he chose to depart from an airport in Belgium because COVID-19 tests were not required at Belgian airports yet at the time of his trip, but rather strict for taking flights from airports in the Netherlands. Some participants stated that health risk was not as significant in their decision not to fly during the pandemic period compared to the inconvenience of additional organizing required due to travel restrictions.

While attitudes towards organizing were generally homogeneous, participants showed heterogeneity in attitudes towards planning. One participant used the expression 'hassle of planning and organizing', suggesting that all planning and organizing are negative for her. We also speculate that planning would be a negative aspect of air travel for the participant who said to enjoy spontaneous trips. However, several participants expressed positive attitudes towards planning, finding it enjoyable or even exciting processes of air travel. They used phrases such as "that (planning) is quite fun", "booking the airplane seats is quite exciting for the family" and "for me the fun of a trip is in the planning beforehand, and at the destination" to convey their sentiments.

Other individual components

Travel companions were mentioned as important determinants of AAT by several participants. In particular, traveling with children was stated to influence air travel in various ways. Some participants considered it very unlikely that they would make air travel plans that include young children, while others included the opinions of their children in destination and route choice planning. Travel companions other than children, such as friends and family, were also stated to influence destination choices. Another interesting observation was the heterogeneous attitudes towards using air transportation. Positive attitudes towards flying were observed with some participants stating that taking flights gives the feeling of going far and adds to the holiday experience in leisure travel. During the discussion regarding the intent to travel by hypothetical

[4] In Dutch, 'plannen' was used for 'planning' and 'organiseren' was used for 'organizing.'

teleportation device, one participant specifically stated that he would prefer to fly to the destination, but teleport when returning home. He explained that on outbound flights he feels excited about the trip and is looking forward to enjoying his time at the destination. On the other hand, on inbound flights, he mentioned that he 'just wants to get home.' While fast transport modes are generally associated with low intrinsic experience values (Lumsdon and Page, 2004), excitement about trying impressive aircraft (A380, Concorde) or even just the experience of flying were also mentioned as positive aspects of taking flights. On the other hand, some participants described taking flights as 'necessary evil,' 'hassle,' or stated that only the activity at the destination is important, with one participant saying "I just want to be there as soon as possible." One participant pointed to the environmental impact of flights as the main reason she avoids traveling by air.

3.4.2.4. Temporal component

The temporal component involves the influence of time windows at which activities are available and the time individuals have to access them (Geurs and van Wee, 2004). In local and regional accessibility, activity patterns are set in the temporal component based on the opening hours of businesses, working hours and daily biological cycles of people. Some participants emphasized the importance of access and egress to and from airports at "logical hours", with several business travel experience group participants prioritizing this over travel costs. For them, aspects like "arriving on time for meetings," "having time to prepare for meetings" or "not being too tired for meetings at arrival" were crucial. These remarks highlight similar time-related constraints in the temporal component of PAA as seen in local accessibility contexts.

In addition to these more generic statements related to the temporal component, there were also remarks highlighting unique characteristics of the temporal component in the context of air travel. First, statements and responses suggested that boarding flights and accessing egress transportation were viewed as activities with time windows themselves. Travelers must factor in time for check-in, security screening, and reaching the destination airport within the operational time frames for egress transportation. Several participants emphasized departure and arrival times as crucial factors to AAT in their responses to the post-survey. During the meeting, one participant specifically stated that she 'only travels using public transportation in the Netherlands' and prioritized departure time over travel costs, as she doesn't like 'departing in the middle of the night.' Conversely, another participant favored late-night departures, citing it as a time 'buffer' during the day before she has to arrive at the airport, in case something goes wrong and additional organizing is needed. Additionally, broader time windows were observed, such as the "right time of the year" and "right time of life," for the participant who mentioned air travel decisions alongside major life choices such as "starting a family" or "getting a dog."

3.5. Conclusions and discussions

3.5.1. Synthesis and conclusions: a framework for PAA

The results from this study generates a framework of PAA which is a partial framework of Geurs and van Wee (2004), with a narrower theoretical scope, but with more details on how the individual component of accessibility influences PAA. Figure 3 illustrates the framework of

PAA from our results. All routes of the contribution of accessibility components to PAA are also present in the framework of Geurs and van Wee (2004). Evidence of feedback loops from PAA back to the accessibility components were not observed from our results. In addition, the indirect effects from the land-use component to the transport component, from the temporal component to the land-use component and from the individual component to the land-use component were not observed in our results. Changes involving the land-use component or transport component may be difficult for individuals to observe as major changes in the characteristics of destinations or the air transportation system takes place over long periods of time.

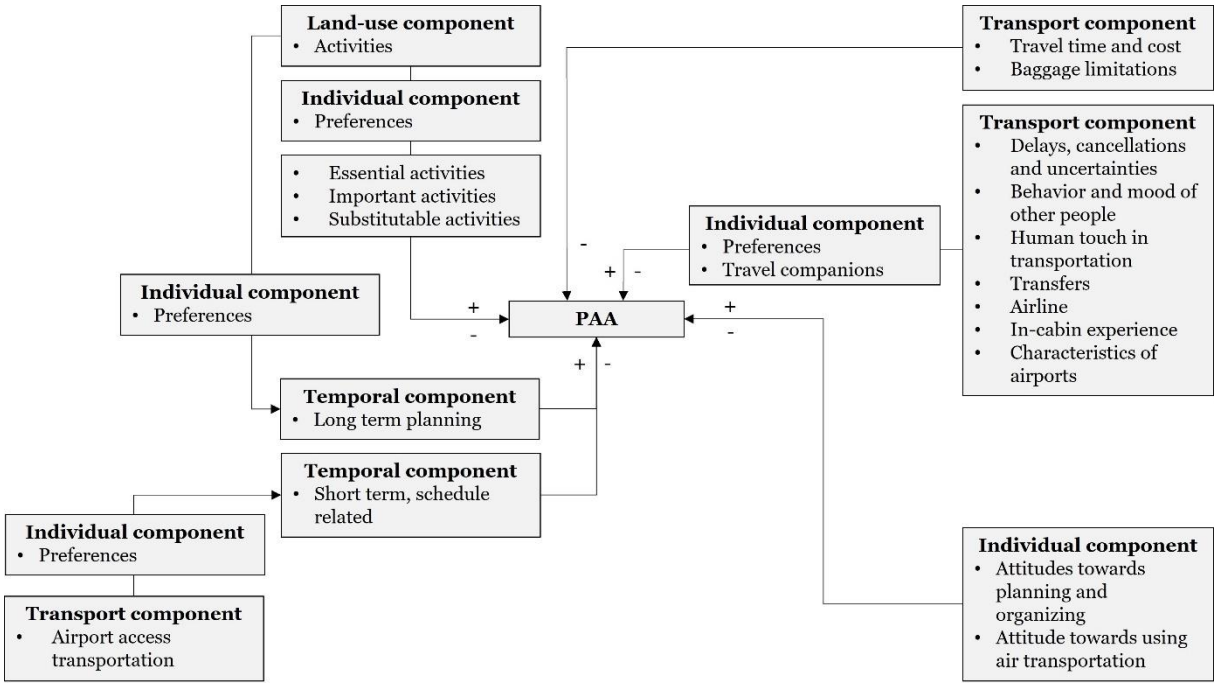


Figure 3. Framework of PAA for (potential) air travelers

Our results supplement the findings of van der Vlugt et al. (2019) in which the difference in outcomes between calculated accessibility and perceived accessibility was observed. Figure 3 demonstrates that the individual component influences the contribution of all accessibility components to perceived accessibility. For the trips made by the respondents, the land-use component has positive contribution to PAA. However, we speculate that this is because the discussions in the FGMs were mainly related to participants' past travel experiences and future travel plans in which the elements of the land-use components are considered to be at least 'acceptable'. In general, there are elements of the land-use component that can negatively impact PAA, such as very high costs, low security levels, or uncomfortable climate conditions etc. at destinations. Travel time and cost, and baggage limitations in the transport component have negative contribution to PAA, while contribution of other elements can vary depending on the specific element and individual preferences or circumstances. The temporal and individual components can also have positive or negative contribution to PAA depending on the specific element and the effect of the individual component. Overall, figure 3 shows that excluding the individual component in accessibility assessments is very likely to lead to mismatches in assessment results and how accessibility is perceived by travelers in real life. The influence of the individual component also leads us to conclude that PAA levels may vary significantly

depending on the characteristics of (groups of) individuals. Even within the groups of participants with the same nationality recruited under specific travel experience requirements, we observed considerable heterogeneity in the individual component. Overall, we consider the individual component to be the key to PAA research, which requires thorough investigation.

3.5.2. Differences between PAA and local/regional perceived accessibility

Based on the results, we found that most differences as mentioned by participants related to the transport component. First, important differences between PAA and local or regional perceived accessibility can be attributed to very high levels of travel costs. Secondly, planning in advance is necessary for booking reasonably priced flight tickets and accommodation. Thirdly, and related, flexibility in making last-minute changes is very low as booking alternative flights or accommodation last minute can be very costly or even impossible. Therefore travelers often have no choice but to rely entirely on the airlines that they booked tickets with even if there are delays or cancellations. A fourth difference between PAA and local or regional accessibility is that PAA requires more organizing.

Regarding the land-use component, we observed that the long distance between origin and destination can increase the attractiveness of destinations or air travel itself for some recreational travelers, which seldom applies to local or regional accessibility contexts. In addition, the results indicate that travelers feel that there are no spatial or geographical boundaries in terms of accessible and inaccessible destinations when it comes to AAT. One participant explained that as long as the attractiveness of activities or destinations to be reached by air travel is high enough, travelers can prepare for the journey and eventually reach the destination. On the other hand, some activities were discussed to be difficult to access by air travel due to strict baggage limitations.

Next we discuss the individual and temporal components. Participants stated that high transportation costs can limit destination and route choices for families as airfare can add up to unaffordable levels in PAA. Additionally, the required ‘organizing’ and ‘planning,’ for even relatively spontaneous trips by flight may lead travelers to perceive AAT as a ‘big undertaking’, a factor that is also related to the individual component. In terms of the temporal component, we observed that selecting the ‘right time to travel’ can be influenced by major life events and long term personal circumstances, in contrast to local or regional accessibility where daily activity patterns and business hours are the main determinants.

3.5.3. Policy and societal relevance

As explained in the introduction section, we draw implications for air transportation climate policy from the results of our FGMs. As results revealed that the importance of the land-use component varies across travel purposes and individuals, we consider that an equitable air transportation climate policy could, at least in theory, aim to maintain PAA levels for essential trips while seeking to reduce emissions from non-essential trips or trips that could be substituted with destinations accessible by transportation modes with lower climate impact. In the literature, replacing short-haul flight services with surface transportation modes has been a topic of research (Baumeister, 2019; Avogadro et al., 2021) for reducing climate impact of air

transportation, while curbing long-haul flight demand has received less attention, although it has the greatest climate impact mitigation potential (Dobruszkes et al., 2022).

Combining the climate impact mitigation opportunities with perceived importance of activities accessible by air transportation, we suggest that curbing demand for non-essential long-haul air travel is a low hanging fruit. This can be achieved to a certain extent by identifying long-distance destinations well known for non-essential activities and assigning high emissions offset costs on those routes. For example, destinations such as Cancun, Bali, or Mauritius are famous beach holiday destinations. For European travelers, there are alternative destinations for beach holidays (such as beach areas of Spain or Portugal) which are accessible by short-haul flights or even high speed rail (HSR). Assigning high greenhouse gas (GHG) emissions offset costs to long-haul beach holiday destination routes may discourage non-essential long-haul flights while maintaining perceived accessibility levels to similar nearby activities that incur lower transportation GHG emissions to access. Such policy may even encourage the use of HSR with longer travel times over short flights, as our results revealed that some travelers find short flight durations with insufficient time to rest or sleep less attractive than longer flights.

Selecting routes to assign high GHG emissions offset costs will depend heavily on which activities can be substituted with less travel distance in the specific regions where the policy planning takes place. At the same time, lower GHG emission taxes for travelers visiting family or relatives on the routes subjected to high emissions offset costs should be planned for equity reasons. However, the frequency of offering lower-taxed airline tickets to a traveler may need to be limited as high-frequency visits, even for visiting relatives, cannot be justified as essential travel. Additionally, the process of applying tax reductions must be concise as additional organizing was described to hinder PAA by the participants of the FGMs. A more generally applicable option could be to tax flights progressively: the first flight a person takes in a certain period (such as a year, or five years) is taxed lower than next flights. This would reduce inequity due to policies that make flying more expensive.

Our findings also reveal opportunities for maintaining perceived long-distance access levels where short-haul flights are banned on routes with rail service. While such policies may be beneficial for reducing the climate impact of transportation, reducing transportation options increase the friction in journeys and may negatively impact perceived accessibility. As transportation costs are determinants of long-distance accessibility, subsidizing long-distance transportation modes with lower climate impact (such as HSR) can play a crucial role in minimizing negative impact on perceived accessibility levels. In addition, improving the on-time performance of low-climate impact long-distance transportation modes and implementing guidelines for clear and prompt communications during schedule disruptions may reduce uncertainty and contribute to enhancing perceived long-distance accessibility by low-climate impact transportation modes. Furthermore, planning long-distance international HSR networks with increased journey lengths without the need to transfer may also decrease friction in accessing long-distance destinations by HSR. Results of the study show that travelers avoid transfers unless the price difference or the location of transfer is attractive enough, and transfers can be deal breakers when the number of transfers exceeds certain thresholds. At the same time, results also revealed that long distances can have a positive contribution to the attractiveness of destinations. For some travelers, being able to travel long distance by HSR with minimal

transfers may be a more attractive option than changes in the land-use component to provide activities closer to home.

Finally, we observed that the names of airlines are often used as indicators for service levels and flight schedule reliability when discussing experiences regarding best and worst air travel experiences. Mandating climate impact scores or ranks to airlines (and flights) in a uniform manner globally and requiring the scores or ranks to be highly visible to travelers may influence the individual component of accessibility by motivating travelers to associate the names of airlines with climate impact. Consequently, airlines with low scores or ranks could adopt climate impact abatement measures more actively as the poor scores or ranks may be bad for business.

3.5.4. Limitations of study

Although FGMs was considered the best method to explore PAA, the study was not without limitations. There were four limitations, two related to FGMs and two limitations from scope of research. First, related to FGMs, results could only be drawn from statements that participants were willing to share openly. There may have been aspects of PAA that participants were reluctant to openly discuss, or which they discussed in a manner that better 'fits in' with the general tone of the discussion of the group. In addition, incomplete knowledge regarding travel attributes, which is one of the potential reasons behind the mismatch between calculated accessibility and perceived accessibility (Pot et al., 2021), may have influenced the opinions or attitudes of the participants. Individual interviews, where the researcher has more time for in-depth investigation, or indirect observation of such factors, by including them as an attribute of choice alternatives in choice models, may be more effective for identifying contributing factors that participants may be less willing to share or for investigating further into possible effects of incomplete knowledge regarding attributes of PAA.

Secondly, whether some factors contributing to PAA mentioned in discussions had a positive or negative impact on PAA could only be speculated from the expressions that participants used and the travel circumstances that they described. For instance, while the best air travel experiences of some participants were focused on good in-flight experiences, it is difficult to determine whether the participants derived positive utility from the flight experiences, or whether the experiences were simply flight experiences with the least disutility. While one participant included a description of good catering during the flight, he also mentioned that he would prefer to skip the flight altogether if teleportation is available.

In relation to the scope of research, the first limitation was that the study was designed to focus on outbound accessibility rather than inbound accessibility. Accessibility levels of the Netherlands as perceived by potential visitors to the Netherlands is a relevant topic for PAA. This is not only important for travelers but also for others such as companies attracting many business trips, the leisure industry, and people being visited by family or friends. However, we consider that this is a broad topic that should be addressed in a separate research designed specifically for this topic. Secondly, our focus on gathering information from real-world experience led participants to discuss past trips. These discussions did not include details about

elements of the land-use component that may have negatively affected PAA to activities at certain destinations they chose not to visit.

The online nature of this research introduced its own set of limitations. Interruptions during speech, an important source of 'semi-verbal expressions' (Trull, 1964), and non-verbal cues like eye contact were hindered in the online setting (Qu and Dumay, 2011). Some participants, who joined from home were interrupted by co-inhabitants. In addition, certain demographics were likely adversely affected by selection effects, the most likely effect being that recruiting elderly individuals posed a challenge as online participation might be less attractive or even not accessible to them. Notably, a segment of older individuals who frequently travel for leisure (e.g., family visits) and could have offered insights, particularly regarding the impact of COVID-19, remained unrepresented. Given that older age is associated with higher susceptibility to severe cases of COVID-19 (Zhang et al., 2022), this absence was especially impactful. Although the unique COVID-19 setting in which this experiment took place provided insights into PAA during a pandemic, we were not able to investigate the full effect of the pandemic as the pandemic and related effects (knowledge about the pandemic and vaccinations, shortage of staff, vaccination policies, travel restrictions, …) continued to develop after the FGMs took place.

3.5.5. Implications for further research

From our results, we discuss potential application of conventional accessibility measures for future quantitative research, answering the third research question in the introduction. For the theoretical basis of empirical studies we consider random utility theory as a strong theoretical basis for PAA research, as is frequently the case in air transportation research (Araghi et al., 2016; Lee et al., 2016; Molin et al., 2017; Choi et al., 2019). Note that utility-based accessibility measures are one category of accessibility measures (Geurs and Van Wee, 2004). As of the time of this research, no academic research articles have been found in which random utility theory was used to study PAA. Results from the FGMs suggested that travelers rationally make travel decisions with little room for impulsive decisions, which adheres to the underlying assumptions of random utility theory (Train, 2009). In addition, statements often indicated that potential travelers consciously make trade-offs among various contributing factors to accessibility (e.g. airfare and the number of transfers, airfare and desired airline, travel time, and attractiveness of destination). Destination or activity substitutability is a topic within PAA suitable for investigation using a utility-based accessibility measure. With appropriate survey design, utility-based measures have the potential to estimate how much GTC savings would be required for travelers to substitute destinations or activities.

Heterogeneity in attitudes towards factors contributing to AAT can also be studied using discrete choice models based on random utility theory. The latent class modeling technique can be useful in addressing heterogeneity as it can be used to check for or identify classes of potential air travelers depending on their preferences regarding contributing factors to AAT. Mixed logit with random parameters is another option for observing the level of preference heterogeneity for factors contributing to PAA. Hybrid choice models can also be used to identify and measure latent attitudinal variables contributing to AAT.

The results also suggest potential accessibility, or gravity-based accessibility (Geurs and van Wee, 2004), as a strong candidate for studying PAA. FGM participants often mentioned that the activities at destinations must be 'worth' the time and cost to reach them, implying that they are generally aware of the attraction of activities and the friction in transportation to reach them. In the PAA context, gravity models must take account of all trip related costs, so both the costs at the destination, as well as the transport costs. The costs at the destination then influence the destination attractivity (land-use component), whereas the transport costs influence the resistance of travel, and thus the transport component. Note that some participants considered both cost types simultaneously in their perception of PAA. For the Dutch travelers' context, our observations suggest that the overall cost of the trip is important in the initial planning stage where potential travelers rule out deal breakers due to unaffordability. In the booking stage, the two different types of costs may be considered separately, with one participant of this study specifically mentioning that costs saved in transport will allow her to spend more at the destination. The effect of distance or travel time for recreational travelers may also require investigation as long-distance increases the attractiveness of destinations (statement romanticizing 'feeling of going far'), but at the same time, increases friction in the transport component.

As for implications specific to future explorative studies aimed at further expanding knowledge regarding PAA, we found that potential air travelers focus heavily on the transportation aspect of accessibility when asked to discuss air travel experiences. We speculate that in the initial planning stage, potential travelers may pay more attention to the land-use component as it is the main reason travelers take trips by flight. This may also provide opportunities for observing the negative contributing factors to PAA from the land-use component. In place of question 2 in the sequence of questions for this study (Table 1), future studies may start the question sequence by asking participants to verbally plan the next trip using air transportation. Next, involving social networks, families, or business partners as participants could provide insights into how AAT is perceived by social groups. Understanding how different groups interact, negotiate, and prioritize travel considerations may be important as travelers often make trips with others ('travel party') and travel planning can be a social event (Fridgen, 1984).

We consider that data collection in an online setting has substantial benefits for PAA research, despite some limitations (see section 5.4) as more diverse participants can be recruited. For local accessibility, relevant FGM participants or interviewees may be located in a relatively small area. This is not the case for PAA research. Online FGMs or interviews can be especially advantageous in recruiting business travelers who may be reluctant to spend time traveling to meeting locations due to their high value of time.

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Chapter 4 Determinants of Perceived Accessibility and Aviation Climate Policy: A Latent Class Analysis of Leisure Air Travelers in The Netherlands[5]

Note: Slightly adapted, changes made explicit in footnotes.

4.1. Introduction

Air transportation accounts for 2.4 percent of anthropogenic greenhouse gas emissions with its contribution to climate change estimated to be almost three time higher when non-CO_2 radiative forcing is considered (Lee et al., 2021). Growth in demand has led to an increase in aviation emissions despite technological advancements in aircraft efficiency (Terrenoire, 2019; Sacchi, 2023) and further growth in demand is expected (Dubois et al., 2011; Airbus, 2025). With technological advancements failing to provide solutions to offset climate impact of air travel, behavioral intervention is crucial.

The World Tourism Organization (2018) distinguishes three purposes for air travel, namely leisure travel, business travel and visiting friends and relatives (VFR). Leisure travel is the most dominant purpose for air travel (Vasigh et al., 2018; Dobruszkes et al., 2019; Dobruszkes et al., 2022). In the Netherlands, 78 percent of air travelers indicated vacations as the reason for their most recent trip by air (Zijlstra and Huibregtse, 2018). At the same time, leisure travel is the

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most expendable and malleable out of the three purposes of air travel (Gössling and Dolnicar, 2023; Yoo et al., 2025), making it the most suitable target for behavioral intervention. Market based measures (Wild et al., 2021; Oesingmann, 2022; Chen et al., 2023), levies and duties (Seetaram et al., 2014; Büchs and Mattioli, 2024), and banning short-haul flights (Avogadro et al., 2021) are some policy measures that aim for behavioral change. Such measures aim to trigger behavioral change by increasing transportation costs or to offset emissions from flying to a certain degree.

In terms of transportation costs, leisure travelers shall be adversely affected by such measures. However, like most transportation, air transportation is a means to an end, and for leisure travelers, the end is the vacation destination that they desire, and flights are a means of accessing them. How the increase in air travel costs affects accessibility of desired vacation destinations cannot be observed by only looking at the transportation. An accessibility framework that covers aspects of both the transportation and the pursued activities is required to assess how air travelers' ability to engage in desired activities is affected. An easy representation is the gravity-based accessibility measure that assesses accessibility using both the attraction of activities or destinations, and the impedance in flow of travelers from the origin to the activity of destination using transportation modes (Keeble et al., 1982). The broader framework of accessibility can also provide insights into how losses in accessibility levels due to higher transportation costs could be reduced or compensated fully through measures unrelated to transportation.

Accessibility has been a topic of study in the field of air transportation research, with studies mostly focused on calculating accessibility levels based heavily on locational and transportation characteristics (Park and O'Kelly, 2017; Dai et al., 2018; Sun and Lin, 2019). However, such calculated accessibility levels do not consider accessibility levels as actually felt by (groups of) individuals. Perceived accessibility is a concept of accessibility that takes into account the abilities, preferences and other characteristics of individuals that can affect the ease of accessing necessary or desired activities. Literature shows that perceived accessibility levels can differ from calculated accessibility levels even in the same context (Martin et al., 2008; Ryan et al., 2016; Lättman et al., 2018; van der Vlugt et al., 2019; Pot et al., 2021).

In the field of air transportation research, perceived accessibility remains an understudied topic (Yoo et al., 2024). Explorative studies have been conducted regarding perceived accessibility by air transportation (PAA) to define accessibility by air from the perspective of travelers and its contributing factors (Halpern and Bråthen, 2011; Yoo et al., 2025). Several studies have included elements of travelers' perceptions regarding aspects of transportation in accessibility assessments (Borodako and Rudnicki, 2014; Cattaneo et al., 2016; Beria et al., 2017; Laurino et al., 2019; Mueller and Aravazhi, 2020; Avogadro et al., 2021; Mueller, 2021). However, these studies do not focus on PAA and only adopt elements of perceptions regarding transportation from existing literature. To assess PAA, knowledge regarding the importance of activities or destinations and the impedance in transportation from air travelers' perspective is needed. Furthermore, while heterogeneity in abilities and preferences of travelers is an essential element of perceived accessibility (Moleman and Kroesen, 2025), heterogeneity in PAA remains understudied. Heterogeneity in preferences of air travelers have been studied in air travel behavior studies (Wen and Lai, 2010; Araghi et al., 2016; Zhou et al., 2020; Moleman et al., 2024). However, the importance of attributes was estimated based on trade-off behavior only

among air transportation attributes rather than trade-off between transportation and destination characteristics. In the field of tourism research, Chen et al. (2019) observed heterogeneity in preferences towards attributes of all-inclusive tour packages in China, and only transfers were included from the transportation component of accessibility. Overall, the effects of determinants of PAA derived from trade-offs between destination attractiveness and the disutility of travel as assumed in gravity-based accessibility (Keeble et al., 1982), along with heterogeneity in preferences of travelers, remain knowledge gaps for operationalizing PAA for policy assessment.

This paper aims to examine the effects of determinants of PAA and reveal heterogeneity in preferences towards these determinants. To achieve this, a stated choice survey for vacation choice was designed to collect data from people in the Netherlands who had taken a vacation by flight within the past three years. The choice alternatives of the stated choice survey consisted of one destination attractiveness attribute and three attributes related to air transportation identified as determinants of PAA from a previous study. To understand destination attractiveness, a separate experiment was conducted in which a profile of six destination attributes were evaluated in a rating scale. For this, linear regression was conducted with the destination attractiveness rating data to estimate the effects of destination characteristics. Ultimately, a latent class choice model (LCCM) was estimated with stated choice data to examine heterogeneity in trade-offs between the utility of destination and the disutility involved in taking vacations across travelers.

Using the method, we addressed the following research questions:

1. Which distinct groups of leisure air travelers can be identified based on their preferences towards determinants of PAA?
2. What are the effects of PAA determinants for each group of leisure travelers?
3. What implications do these heterogeneous preferences have for the design of market-based aviation climate policies that increase vacation costs?

The next section provides a conceptual framework of the study followed by a description of the methodology in section 3. Section 4 provides the results and discussions regarding policy implications are made in Section 5. Finally, conclusions are drawn in Section 6.

4.2. Conceptual framework for measuring the importance of PAA determinants

Given that decisions regarding vacations by air travel for most people are not frequently made and require major expenditures and advance planning, we assume that air travelers are motivated to make deliberate, utility-maximizing decisions. Therefore, we use the methodological approach of utility-based accessibility measures to estimate the effects of PAA determinants. Under the random utility theory, it is assumed that travelers make rational choices that maximize utility considering the attributes of choice alternatives (Train, 2009). Utility-based accessibility measures derive accessibility from the logsum of multinomial logit (MNL) models (Geurs and van Wee, 2004). In this study, PAA determinants are set as attributes of

vacations, and the attribute parameters estimated from discrete choice models reveal the effect of each PAA determinant.

In focus group discussions regarding accessibility by air transportation, Yoo et al. (2025) observed that travelers consciously make trade-offs between the disutility of the journey and the attractiveness of activities to decide whether the journey is worth tolerating to engaging in desired activities. This is in line with gravity-based accessibility, in which accessibility is determined by the attractiveness of destinations and the transportation impedance for reaching the destinations. Based on utility-based accessibility approach and the underpinnings of gravity-based accessibility approach, we assume that leisure travelers trade-off destination attractiveness with elements of transportation impedance from air travel. In order to better understand these trade-off, we conduct a stated choice experiment, in which people have to make choices between combinations of destination attractiveness and travel attributes.

Destination attractiveness, however, is an intangible perception that provides little information for analyzing travel behavior. To anticipate the attractiveness level of real word vacation destinations, information regarding the influence of the contributing factors on destination attractiveness is needed. To study the contributing factors, in analogy of the hierarchical information integration (HII) approach (Louviere, 1984), which assumes that decision makers classify attributes into higher order decision constructs when there are too many attributes to consider in one decision, we assume that destination attractiveness is such a higher order decision construct. Following this approach, we conducted a second experiment to determine the attractiveness of destinations based on characteristics of vacation destinations. Thus, this experiment reveals how destination attractiveness is influenced by destination characteristics and the choice experiment reveals how destination attractiveness is traded-off against travel attributes.

For inclusion in the choice experiment, PAA determinants that act as transportation impedance were identified from the focus group study by Yoo et al. (2025). In this study, the overall vacation cost, including spendings at destinations, was observed as a critical determinant. When the overall vacation cost exceeds the maximum vacation budget, it becomes a deal-breaker. Thus, the cost component goes beyond transportation impedance and can be considered as overall impedance in PAA of vacations. Therefore, we use the term impedance henceforth rather than transportation impedance. Another element of impedance observed to be a PAA determinant was travel time. To include the overall time of accessing vacation destinations, door-to-door travel time was selected as a determinant. Finally, the study by Yoo et al. (2025) revealed that flight schedule disruptions and airlines' handling of such situations are major determinants for Dutch air travelers. Accordingly, flight schedule reliability was included as a PAA determinant for impedance.

For the PAA determinant of destination attractiveness, we identify six contributing factors. First, destination type is considered as an important characteristic of a destination as it is closely related to the vacation activities that travelers wish to engage in (Özdemir, 2022). The second characteristic we consider is cost of living levels at vacation destinations (Martin and Witt, 1987). Cost of living levels not only allow respondents to anticipate spendings at destinations, but can also reflect the economic development of the destinations. Economic development of the destination may be correlated with perceived risk at the destination and effort required to

carry out essential activities during the stay at the destination. The third characteristic we consider is familiarity with the destination, identified by Yoo et al. (2025). For travelers looking for relaxing holidays may value familiarity as it reduces the risk of uncertainty disturbing relaxation (Cohen, 1979) while for travelers seeking variety (Nicolau, 2008), familiar destinations can be unattractive. The fourth characteristic of destination attractiveness that we consider is temperature. Travelers who seek to engage in active outdoor activities may prefer mild temperatures (Kozak, 2002) while travelers seeking to engage in activities in water may prefer higher temperatures. For the fifth contributing factor, Yoo et al. (2025) observed that prearrangements to meet travel requirements hinder PAA. Destination specific prearrangements can include border control documents or vaccination requirements. Finally, recent accessibility literature suggests that positionality of vacation destinations may be a contributing factor to vacation destinations (Van Wee, 2021; Van Wee and Mokhtarian, 2025). Positional goods are those with utility that depend on the behavior of others (Hirsch, 1976). Scarcity (Hirsch, 1976), self-image and perceptions of others (Johansson-Stenman and Martinsson, 2006), and status (Carlsson et al., 2007) are some driving factors behind the utility of positional goods. For vacation destinations, the utility that a traveler derives from a certain destination may decrease if the traveler finds out that her peers have traveled to more attractive destinations (Molin et al., in press). Positionality has not yet been studied in the context of vacation destinations and results regarding positionality may offer new insights into the utility that travelers derive from vacation destinations.

Next, the effects of the determinants on PAA depends on individual characteristics. More specifically, socio-demographic characteristics, frequency of air travel and personal importance of vacations may relate to the impact of PAA determinants. Socio-demographic characteristics are frequently associated with systematic differences in travel behavior, resource constraints, and vacation motivations (Kozak, 2002; Hsu et al., 2009; Almeida-Santana and Moreno-Gil, 2018; Özdemir, 2022), and may therefore explain variations in attribute sensitivities across individuals. Air travel frequency was selected as a criterion for segmenting travelers with the purpose of revealing preferences of groups that travel more frequently than others. Similarly, the influence of personal importance of vacations was considered relevant in identifying traveler groups, as behavioral intervention policies aimed at groups that do not assign high value to vacations by air can have relatively low impact on PAA of vacations. The type of vacation that the respondents most frequently engage in using air travel was also taken into consideration as traveler groups that share similar preferences for activity types may also share preferences regarding air travel[6]. Finally, presence of children in the typical travel party was taken into consideration as traveling with children may affect air travel preferences (Yoo et al., 2025; Graham and Metz, 2017).

Figure 1 is an illustration of the conceptual framework underlying this study. Vacations with strong destination attractiveness and low impedance derive high utility for travelers and travelers would choose vacations based on the utility that they derive from vacation options. We assume that the utility travelers derive from vacation options and preferences regarding

[6] The variable "type of vacation most frequently engaged in using air travel" was not included in the manuscript submitted for publication, as it did not contribute to the modeling outcomes nor the study's conclusions. It was, however, included in the thesis chapter, since its lack of contribution is relevant to the broader conclusions of the thesis.

PAA determinants are heterogeneous across individuals as tastes and personal circumstances vary. Individuals that share certain characteristics or tastes may have homogeneous preferences that are distinct from other groups of individuals with different characteristics or tastes. Accordingly, each of these groups may derive varying utility levels from vacation options, leading to different vacation choices. Based on observations of vacation choice, we estimate the effects of PAA determinants for each latent class of travelers. Among the PAA determinants, destination attractiveness is assumed to be a decision construct that is determined by a set of destination characteristics.

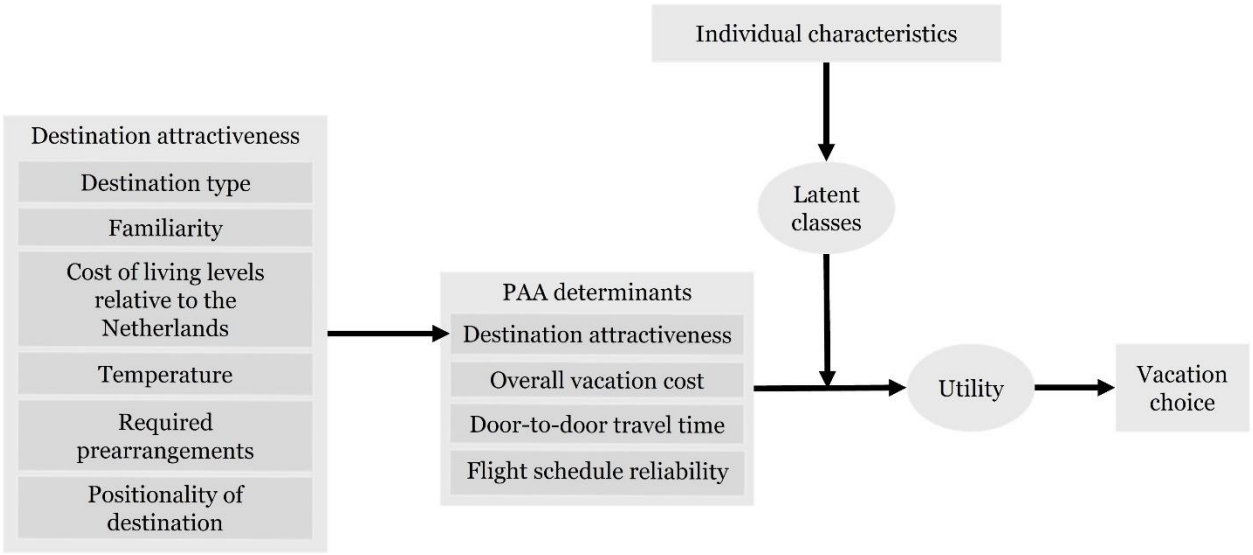

Figure 1. Conceptual framework for measuring the effects of PAA determinants

4.3. Methodology

4.3.1. Survey design

To assess the influence of PAA determinants and destination attractiveness on vacation choice, a survey with a vacation choice experiment and a destination attractive rating experiment was designed. The HII approach provided the benefit of avoiding overly complex choice tasks that may have resulted in unreliable responses due to information overload (Molin and Timmermans, 2009). For both experiments, respondents were asked to assume that they are considering vacation options for an upcoming two-week summer vacation by air travel, accompanied by the typical travel companions that they take vacations with. In the final part of the survey, respondents were asked about their background information. The experiments were designed using the software Ngene and later written into presentable format on the online platform Qualtrics. We further explain the details of the two experiments below. We first describe the main experiment (the choice experiment) followed by the destination attractiveness rating experiment for studying the decision construct.

4.3.1.1. Vacation choice experiment

The choice tasks were presented in which respondents were asked to select the most attractive vacation alternative from three alternatives, each consisting of the four attributes in the PAA determinants box of Figure 1. All attributes varied in three levels. Table 1 presents the attributes of vacation alternatives and their levels. Explanation regarding attributes of vacations and their levels were provided before the choice tasks were presented. An opt-out alternative was not included in the stated choice experiment as the objective of the experiment was to examine trade-offs between destination attractiveness and air transportation attributes among individuals considering an air vacation. Therefore, respondents were asked to choose between vacation alternatives rather than between traveling and not traveling. Furthermore, responses that selected the opt-out option would not provide any information on the trade-offs between attributes, potentially resulting in parameters that are not statistically significant. As one of the aims of the study was to measure the effects of PAA determinants, we considered it more important to focus on acquiring meaningful parameter estimates than to collect data on opt-out conditions.

The levels for destination attractiveness varied from six to eight on a ten-point scale in which one represents the least attractive and ten represents the most attractive. The destination attractiveness rating tasks preceded the vacation choice tasks and respondents were asked to refer back to the rating scale and destination attributes in the rating tasks. In the exam grading scales in Dutch schools, six is universally considered as the threshold for an acceptable level while nine or ten are given very rarely only for exceptional cases. This idea is prevalent for Dutch people when using ten-point scales in evaluations or expressing satisfaction or judgements, which are widely used in Dutch surveys. Accordingly, we assumed that destinations with attractiveness levels below six would not be included in the consideration set of travelers, thus immediately rejected. Furthermore, in a holiday destination choice study in the Netherlands, Ceha (2024) rarely observed the scores of nine and ten and in a destination rating experiment, and alternatives with those destination attractiveness scores in a choice experiment were always chosen over alternatives with lower destination attractiveness scores. Thus, destinations with attractiveness levels nine and ten would be considered exceptional, and to avoid creating dominant alternatives, we limited the destination attractiveness levels to the scores 6,7 and 8.

Cost was explained as the overall cost of vacation including airfare and costs at destination for all travel companions that the respondent pays for. Respondents were asked before the choice experiment to select their typical vacation budget for a two-week vacation by air for themselves and all travel companions that they typically pay for. Attribute levels of cost varied from 20 percent lower to 20 percent higher, pivoting from the vacation budget that each respondent selected before starting the choice tasks. Thus, the attribute levels were customized for each respondent and displayed in absolute values in Euros. For model estimation, vacation cost levels required standardization as the cost attribute levels represent overall costs for the respondent and all travel companions. In addition to their overall vacation budget, respondents were asked to state the number of travel companions that they usually pay for, before starting the choice tasks. The attribute levels for cost were converted to ‘cost per person’ for model estimation.

Door-to-door travel time was explained as one-way travel time and respondents were reminded to consider around five hours of origin airport access time, waiting time and destination airport egress time. Therefore, the attribute level '10 hours' indicated a destination reachable by 5 hours of air travel.

Schedule reliability reputation of airlines and route was explained as both the reputation for schedule reliability of the route and the airline that serves it, and disruption handling by the airline. 'Reliable' referred to routes with reliable schedules. 'Adequate handling' of schedule disruptions was explained as adequate communications regarding modified schedules and reasons for disruption, accompanied by adequate compensation. 'Inadequate handing' was explained as inadequate communications which leave travelers in the dark about modified schedules and reasons for disruption, and/or inadequate compensation.

Table 1. Vacation choice experiment attributes and levels.

Attribute	**Levels**
Destination attractiveness	1. 6 out of 10 2. 7 out of 10 3. 8 out of 10
Cost	1. 20% lower than selected budget 2. Equal to selected budget 3. 20% higher than selected budget
Door-to-door travel time	1. 10 hours 2. 15 hours 3. 20 hours
Schedule reliability reputation of airline and route	1. Reliable 2. Known for schedule disruptions with adequate handling 3. Known for schedule disruptions with inadequate handling

Applying a d-efficient design, a total of 18 choice tasks were created, each with three vacation alternatives. The 18 choice tasks were divided into two blocks, with nine choice tasks being assigned to each survey. Figure 2 is an example of the vacation choice task.

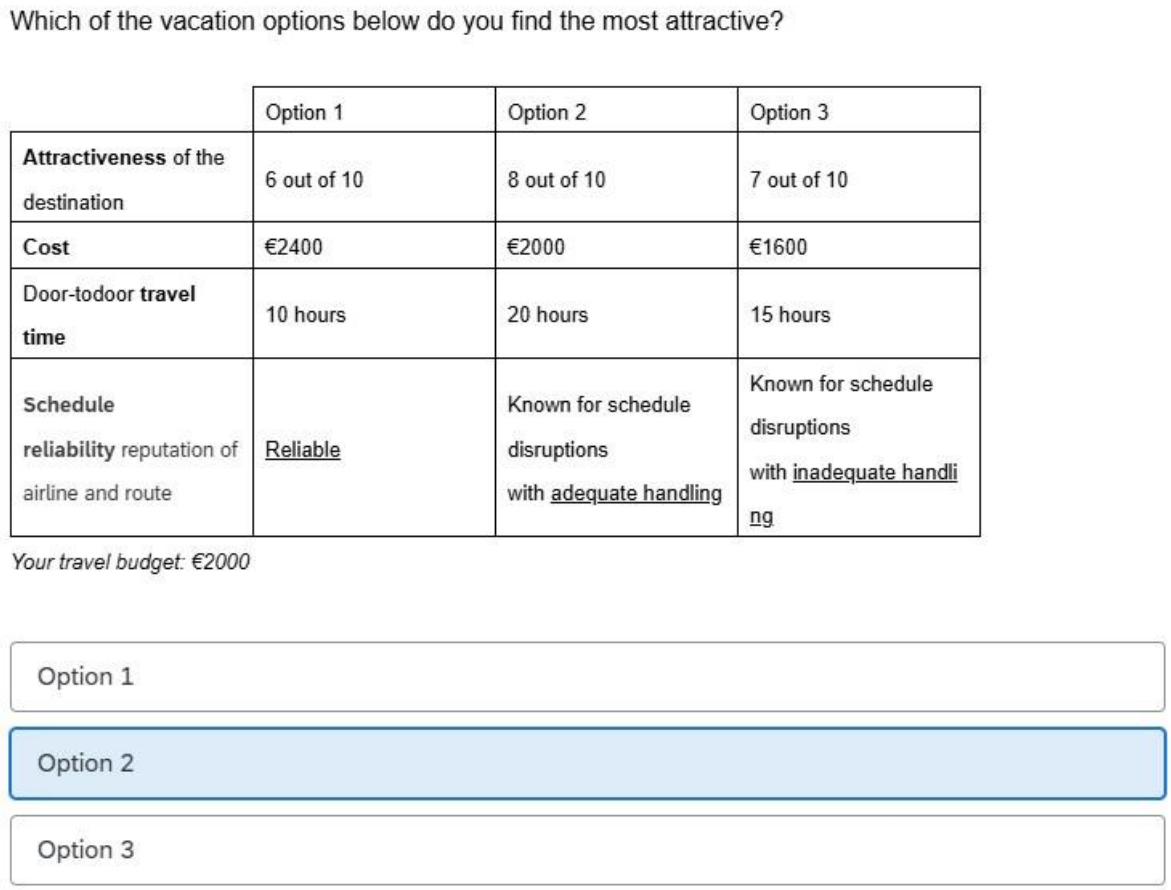

Figure 2. Example of the vacation choice task

4.3.1.2. Destination attractiveness rating experiment

As discussed before, the purpose of the destination rating experiment was to collect data for analyzing how destination characteristics influence destination attractiveness. Six destination attractiveness characteristics listed in Figure 1 were presented with varying levels to describe the destination. All attributes varied in three levels. Respondents were asked to rate the attractiveness of destinations on the earlier discussed 10-point rating scale.

Table 2 presents the attributes and the levels. Destination type was presented as 'The destination is famous for…' and consisted of levels 'enjoying nature', 'exploring culture and social aspects' and 'relaxing vacations'. Explanations of the levels were provided in the questionnaire before the rating task questions were shown. 'Enjoying nature' referred to destinations that are known for activities in nature such as camping, hiking, cycling or kayaking in natural environments. 'Exploring culture and social aspects' referred to destinations where the main attractions are related to culture and traditions including local social events, performing arts, museums, city tours, local markets etc. 'Relaxing vacations' referred to destinations known for holiday resorts with facilities such as pools or beaches, restaurants, wellness spa etc.

Familiarity varied among 'visited before', 'heard about from others' and 'relatively unknown'. 'Heard about from others' was explained as having heard about the destination from a personal acquaintance that had been to the destination. This would involve the respondents having been

able to hear personal experiences of someone they know well. 'Relatively unknown' was explained as destinations to which nobody the respondents know have traveled to before. Therefore, the respondents would have to rely on information from sources that they do not know personally.

Temperature ranges at the destinations were set to three levels to represent mild, warm and hot temperatures. While some travelers may prefer colder temperatures, extending the lower limit to below 18 degrees Celsius presented a challenge in designing realistic rating tasks. Destinations with temperatures below 18 degrees Celsius in July and August (such as Reykjavik, Queenstown, high altitude Banff area of Canada, St. John's in Newfoundland and Labrador of Canada) consist mostly of destinations known for enjoying nature, and in some cases relaxing holidays, but not for exploring culture and social aspects. Accordingly, the survey design would have required introduction of correlation between temperature and destination type to present realistic destinations for the rating task. To avoid introducing correlation, the lowest temperature range was set to 18 degrees Celsius to 24 degrees Celsius taking into account the insights from Lise and Tol (2002), who reveal that 21 degrees Celsius is the ideal temperature for the large bulk of international tourists.

'Cost of living levels' was described as 'the difference in cost levels compared to going on a comparable vacation in the Netherlands.' Although Martin and Witt (1987) suggested the use of 'tourist's cost of living', such data was not available, and we consulted the cost of living index from Numbeo (2025). While data from 139 countries showed cost of living levels ranging between 71 percent lower to 63 percent higher than the Netherlands, we opted for a range varying from 45 percent lower to 15 percent higher to avoid extreme cost of living level differences leading to dominance by the cost of living attribute. This range included most of the countries famous for holidays for Dutch travelers. 45 percent lower, 15 percent lower and 15 percent higher were set as alternative levels for equidistance.

Positionality was presented as 'destination attractiveness compared to vacation destinations that your family, friends or other people you know well have been to,' as respondents may not be familiar with the term 'positionality.'

Required prearrangements were described as arrangements that may be specific to destinations such as visa, ESTA or vaccination requirements. '1 action' referred to a single vaccination shot or online border control document application and 'multiple actions' referred to multiple vaccinations or visa application procedures spread out over a period of time.

Table 2. Destination attractiveness rating experiment attribute and levels

Attribute	Levels
The destination is famous for…	1. Enjoying nature 2. Exploring culture and social aspects 3. Relaxing vacation
Familiarity	1. Visited before 2. Heard about from others 3. Relatively unknown
Temperature	1. 18°C - 24°C 2. 24°C - 30°C 3. 30°C - 36°C
Cost of living levels relative to the Netherlands	1. 45% lower 2. 15% lower 3. 15% higher
Destination attractiveness compared to vacation destinations that your family, friends or other people you know well have been to	1. More attractive 2. Equally attractive 3. Less attractive
Required prearrangements	4. none 5. 1 action 6. Multiple actions

To construct this experiment, a fractional factorial orthogonal design with 18 destination alternatives was generated and blocked into three blocks with six alternatives each. We considered that respondents' preferences for destination type and temperature may be correlated. Respondents that seek to enjoy nature during their vacations may prefer a destination suitable for such activities with mild temperatures while respondents seeking to relax near beaches or pools may prefer hot temperatures. Therefore, an interaction term between 'destination type' and 'temperature' was included in the experiment design. Figure 3 provides an example of the destination attractiveness rating task.

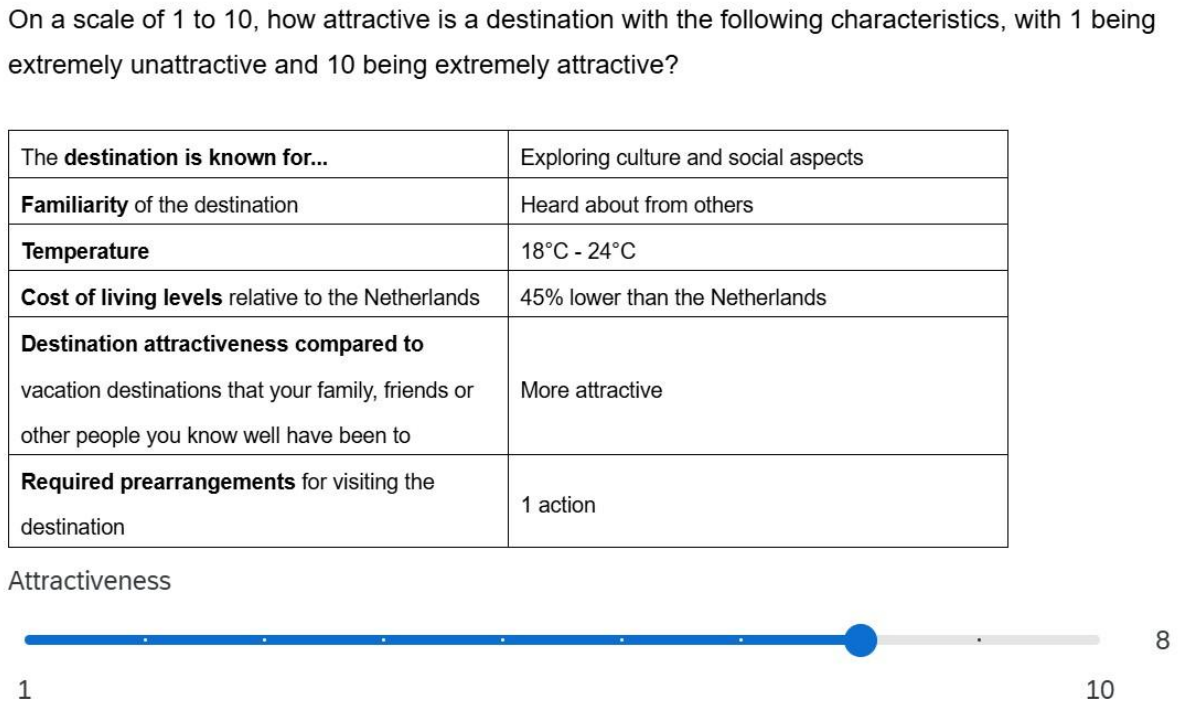

Figure 3. Example of the destination attractiveness rating task

4.3.1.3. Background variables

The final part of the survey consisted of questions regarding characteristics of travelers. Questions regarding socio-demographic information included gender, age, income and highest completed education level. Two questions regarding air travel frequency were also included. The first question asked how many leisure trips by air respondents had in the past three years, and the second question asked how many business trips they had. For 'personal importance of vacations,' respondents were asked to rate the statement 'vacations by air are more important for me than other hobbies or free-time activities that I engage in' on a 5 point Likert scale (1 = strongly agree, 5 = strongly disagree).). The respondents were also asked to indicate whether children were included in the travel party that they are financially responsible for.

4.3.2. Data collection and sample description

Survey responses were collected online in August 2025. The population was defined as leisure travelers that have traveled by air for a vacation in the past three years entirely with their own funds. The population was defined as such to focus on PAA of the group of air travelers with highest level of flexibility in travel destinations and most suitable for behavioral intervention. Hence, this excluded vacations combined with business trips, partially paid by employers or business, or vacations paid by family members other than partners or spouses, in which the traveler may not be the main decision maker in destination choice. To that effect, two filter questions were placed at the beginning of the survey to limit the sample to those with experience in going on vacations by flight within the past three years and those that stated that they would spend €750 per person or more for a vacation lasting around two weeks. The three-year period was set to exclude travel experience from the COVID-19 period when air travel experiences

may have been very different. €750 per person was selected as the minimum budget as any amount lower than €750 could result in an unrealistic alternative with 'overall vacation cost' attribute showing levels under €600 for a two-week vacation at a long-distance flight destination.

A survey company, Panel Inzicht (https://panelinzicht.nl), distributed the survey among its panel members, which in total amounts to more than 150,000 members in the Netherlands. In total 500 responses were collected. Despite the filter question for the minimum budget requirement, 54 respondents chose a combination of vacation budget and number of travel companions for whom they pay for vacations amounting to less than €750 per person. These responses were removed manually. The final sample consisted of 446 respondents.

Table 3 shows the description of the background characteristics of the sample. The majority of the respondents were above 30 years of age. We consider that the travel budget requirement of over €750 per person may have filtered out younger people with lower income or disposable income, who may also be more inclined to travel for leisure when it is possible to combine motives (business and leisure, VFR and leisure) to lower costs. 78.9 percent of the respondents had not traveled for business in the past three years and would not have had opportunities to combine business trips with vacations. This implies that a large portion of the sample would usually have discretion over vacation destinations rather than being limited to a vacation destination in the region of business trips.

Table 3. Distribution of background characteristics

Distribution of background characteristics (N=446)	
Gender	
Male	47.5%
Female	52.2%
Non-binary	0.2%
Age	
19-30	7.2%
31-50	28.9%
51-64	29.8%
65+	34.1%
Gross household income	
Low (€0 - 29,999)	12.8%
Middle (€30,000 - 59,999)	37.2%
High (€60,000 +)	31.6%
Prefer not to say	18.4%
Education level	
Low (Basisonderwijs, VMBO	16.4%
Mid (HAVO, VWO, MBO)	72.2%
High (HBO, WO, Doctorate)	11.2%
Prefer not to say	0.2%
Frequency of air travel in the past three years for strict personal purposes	
Less than once a year	42.8%
Once a year	18.8%
More than once a year to twice a year	25.8%

More than twice a year to four times a year	10.8%
More than four times a year	1.8%
Frequency of air travel in the past three years for business purposes (including those where leisure was combined)	
None	78.9%
More than none but less than once a year	11.4%
Once a year	2.5%
More than once a year to twice a year	3.8%
More than twice a year to four times a year	1.6%
More than four times a year	1.8%
Importance of vacations: vacations by air are more important than other hobbies	
Strongly disagree, disagree	43.0%
Neutral	23.5%
Agree, strongly agree	33.4%
Presence of children in typical travel companions	
Yes	23.8%
No	76.2%
Type of vacation most frequently engaged in using air travel[7]	
Enjoying nature	14.1%
Exploring culture and social aspects	38.6%
Relaxing vacation	47.3%

4.3.3. Model estimation

A MNL model and a LCCM was estimated with the vacation choice data using the software LatentGold 6.1. LCCM is a discrete choice logit model that assumes that a finite number of heterogeneous latent segments exist within the sample, each characterized by its own set of utility parameters. Preferences are homogeneous within a class, while preferences across the population vary between classes. It estimates preferences towards attributes for each segment and a class membership model that statistically predicts an individual's probability of belonging to each segment based on their characteristics (Greene and Hensher, 2003). LCCM provides behaviorally meaningful market segments without imposing parametric distributional assumptions on taste heterogeneity.

Starting from a single-class MNL model, latent class models with increasing numbers of classes were estimated sequentially without covariates for class membership. The 'schedule reliability reputation' is a nominal variable and therefore was dummy coded with 'reliable schedule' set as the baseline. Following the standard practice of estimating LCCM, the optimal model was determined by comparing goodness-of-fit with Bayesian information criterion (BIC), and by evaluating the behavioral interpretability of the attribute parameters, BIC applies a stronger penalty to model complexity than other criteria and is therefore widely recommended for

[7] The variable "type of vacation most frequently engaged in using air travel" was not included in the manuscript submitted for publication, as it did not contribute to the modeling outcomes nor the study's conclusions. It was, however, included in the thesis chapter, since its lack of contribution is relevant to the broader conclusions of the thesis.

determining the number of classes in latent class choice models, helping to avoid overfitting as class numbers increase (Nylund et al., 2007). The following utility function was used for the MNL model estimation. The utility that individual (n) derives from vacation alternative (i) is specified as:

$$U_{ni} = \beta_{ATT} ATT_{ni} + \beta_{COST} COST_{ni} + \beta_{TIME} TIME_{ni} + \beta_{ADEQ} ADEQ_{ni} + \beta_{INADEQ} INADEQ_{ni} + \varepsilon_{ni}$$

ATT_{ni} denotes the destination attractiveness level, $COST_{ni}$ denotes the overall vacation cost per person, $TIME_{ni}$ denotes the door-to-door travel time, $ADEQ_{ni}$ is a dummy variable equal to one if the route is known for schedule disruptions with adequate handling and zero otherwise, and $INADEQ_{ni}$ is a dummy variable equal to one if the route is known for schedule disruptions with inadequate handling and zero otherwise. The reference category for schedule reliability reputation is 'routes known for reliable schedules'. The error term ε_{ni} captures unobserved influences on utility and is assumed to be independently and identically distributed according to the type I extreme value distribution.

For the LCCM, the same utility specification is adopted, but the parameters are allowed to vary across latent classes:

$$U_{nis} = \beta_{ATT,s} ATT_{ni} + \beta_{COST,s} COST_{ni} + \beta_{TIME,s} TIME_{ni} + \beta_{ADEQ,s} ADEQ_{ni} + \beta_{INADEQ,s} INADEQ_{ni} + \varepsilon_{nis}$$

where (s) denotes the latent class and the class-specific parameters, and $\beta_{k,s}$ denotes the coefficient associated with attribute $k$for latent class s.

After identifying the LCCM with optimal number of classes, the individual characteristics in Figure 1 were included as covariates. All individual characteristics were initially included as covariates. Covariates with the lowest statistical significance were subsequently removed one at a time, with the model re-estimated after each step, with the goal of including only covariates significant at the 95% confidence level.

Table 4 shows the model fit for LCCMs with different numbers of classes. Each added class improved model fit, but the four-class model showed an unexpected sign in an attribute parameter making it difficult to trust the results. Adding the membership function revealed that none of the individual characteristics, apart from 'age,' showed statistically significant contribution to improving membership probability. Therefore, a three-class model with 'age' as the only variable in the membership function was selected as the final model.

Table 4. Model fit for two to four class LCCM

Number of segments	Number of parameters	Log likelihood at convergence	Adj rho square	AIC	BIC
1	5	-3306.049	0.000	6622.099	6642.600
2	11	-3020.189	0.083	6062.378	6107.481
3	17	-2867.876	0.127	5769.752	5839.458
4	23	-2802.083	0.145	5650.166	5744.473

A linear regression analysis was conducted to estimate the effects of destination characteristics on the destination attractiveness higher order decision construct. We did not anticipate linear parameters for all attribute levels. Therefore, all attributes were effects-coded, such the regression constant represents the average rating observed for all constructed alternatives and the parameter estimates represent deviations from this grand mean.

4.4. Results

This section presents and discusses the results of the estimated models, starting with the regression analysis of the destination attractiveness decision construct for the entire sample. This is followed by the MNL results on the vacation choice data. Finally, the LCCM results are presented, and characteristics of the identified latent classes are discussed.

4.4.1. Destination rating regression analysis of overall sample

The linear regression results in Table 5 show how much each of the destination characteristics contribute to the attractiveness of the destination. Cost of living levels at destinations show strong influence on destination attractiveness, with travelers preferring destinations where the cost of living is lower than the Netherlands and very strong dislike for destinations with higher cost of living. However, there is only marginal difference in travelers' preferences between destinations with cost of living levels 15 percent lower and 45 percent lower than the Netherlands. The attribute with the second strongest influence is temperature with travelers showing tendency to avoid hot temperatures. Positionality of destinations shows similar contribution to destination attractiveness as temperature. Travelers show slightly higher preference for destinations 'more attractive' than those of peers compared to 'equally attractive' destinations. However, the 'less attractive' positionality level has strong negative influence on destination attractiveness. As for 'prearrangement requirements,' having to perform 'multiple actions' to meet requirements for entering a destination country has strong negative influence on destination attractiveness. Having to perform '1 action' slightly reduces convenience compared to destinations requiring no action, but it is still perceived positively overall. What is noteworthy is that not only are the parameters of 'positionality of destinations' statistically significant, but they also have stronger influence than 'prearrangements,' which was identified as a PAA determinant from a study performed with Dutch air travelers. This confirms that vacation destinations have characteristics of positional goods. It also reveals that rather subjective elements such as positionality can have stronger effect on perceptions regarding destination attractiveness than elements involving actual actions that travelers need to partake in. The influence of the 'type of activity the destination is famous for', and 'familiarity of destination' on destination attractiveness are not statistically significant. We suspect that heterogeneous preferences for destination type and familiarity cancel each other out at the aggregate level resulting in statistically insignificant parameters.

Table 5. Destination attractiveness rating linear regression results from overall sample

	Parameter	t-ratio
Intercept	5.014	38.026
The destination is famous for…		
Enjoying nature	-0.128	-1.445
Exploring culture and social aspects	-0.188	-2.123
Relaxing vacation	*0.316*	
Destination familiarity		
Visited before	0.163	1.832
Heard about from others	0.017	0.198
Relatively unknown	*-0.181*	
Temperature range		
18°C - 24°C	0.503	5.674
24°C - 30°C	0.664	7.487
30°C - 36°C	*-1.167*	
Cost levels for staying at destination relative to the Netherlands		
45% lower	0.875	9.907
15% lower	0.867	9.758
15% higher	*-1.742*	
Positionality of destination compared to destinations of friends, family or other people you know well		
More attractive	0.621	7.031
Equally attractive	0.543	6.160
Less attractive	*-1.165*	
Prearrangements required to travel to destination		
No action required	0.448	5.067
1 action	0.290	3.268
Multiple actions	*-0.738*	

4.4.2. MNL Results

Table 6 shows the parameters and t-ratios for each attribute. All four attributes turned out to have a statistically significant influence on utility of vacations, and all parameters had expected signs with utility increasing with higher destination attractiveness and lower travel time, cost and risk of disruptions. The results show that risk of schedule disruptions causes a substantial negative effect on utility within the attribute levels varied in the experiment. In this context, flight routes with reputation for schedule disruptions are considered to cause more disutility than the utility increase that can be expected from a destination with one level higher attractiveness. This is in line with the findings of Landau et al. (2016) in which they observe significantly higher value of time (VoT) for time spent during delays. The negative effect on utility is almost three times higher when there is risk of inadequate compensation for schedule disruptions. When compared to the utility contribution of destination attractiveness within the range of six to eight, the results suggest that travelers may not choose a destination that is one level higher in attractiveness if the route is known for schedule disruptions. Nevertheless, destination attractiveness is also an influential attribute. Dividing the parameter of attractiveness level by the parameter of overall vacation cost per person indicates that travelers

are on average willing to pay €485 per person to travel to a destination that is considered one level higher in attractiveness.

In the same manner, the willingness-to-pay (WTP) to visit a destination with less door-to-door travel time can be calculated. Within the context of the experiment, this amounts to €68 to travel to a destination requiring one hour less in travel time. This is higher than the official Dutch in-flight VoT of €54 (€60 corrected for inflation) per hour by the Netherlands Institute for Transport Policy Analysis (KiM) for air travelers traveling for private purposes (Knoope, 2023). The estimated WTP of approximately €68 per hour is broadly comparable to the VoT of approximately €60 per hour reported by KiM for private air travelers. However, the two estimates are not directly equivalent. KiM's value of time is derived from trade-offs between transport time and transport cost, whereas our estimate is based on trade-offs between more general PAA determinants, door-to-door travel time and overall vacation cost. Consequently, our estimate reflects travelers' valuation of travel time within the broader context of vacation decision-making rather than within the transport component alone.

We suspect there are three possible reasons behind the somewhat higher WTP to travel to a destination with shorter travel time compared to KiM's VoT value. First, travelers in our study could be less sensitive to overall vacation costs compared to transport costs alone, resulting in higher WTP values for shorter travel time than VoT based on transport costs. Higher vacation costs could have been associated with higher quality of vacation. Second, the group of air travelers with very high sensitivity to cost were excluded from our sample, as the sample only included travelers that spend €750 or more on vacations. Third, certain journey segments included in the door-to-door travel time could have been perceived to cause higher disutility than by flight times.

When comparing travel time with destination attractiveness, travelers would be willing to tolerate an extra seven hours of travel time if they can reach a destination that is considered one level higher in attractiveness. Thus, motivating travelers to reduce flight distance for vacations would be difficult unless destinations that are likely to be considered highly attractive in nearby regions are identified and promoted.

Table 6. Parameters and statistical significance from MNL model

	Parameter	t-ratio
Attributes		
Destination attractiveness	0.436	17.227
Overall vacation cost per person	-0.0009	-12.806
Door-to-door travel time	-0.061	-13.310
Route known for robust schedule (reference)		
Route known for schedule disruptions with adequate compensation (dummy)	-0.782	-19.707
Route known for schedule disruptions with inadequate compensation (dummy)	-2.102	-35.583
Respondents	446	
Observations	4014	
ρ^2	0.2507	
AIC	6622.099	
BIC	6642.600	

4.4.3. Results from three class segmentation using LCCM

Table 7 shows the parameters and statistical significance of attributes for vacation choice per each latent class identified through LCCM. To understand the destination preferences of the identified classes, we estimated a destination attractiveness regression model for each of the three classes. The results are presented in Table 8. In the following, we discuss the characteristics of the identified classes both in terms of the choice attributes and the destination attractiveness preferences, focusing on how each class differs from the overall sample.

Table 7. Vacation choice LCCM results

	Class 1		**Class 2**		**Class 3**	
	Parameter	t-ratio	Parameter	t-ratio	Parameter	t-ratio
Attributes						
Destination attractiveness	1.005	15.437	0.061	0.672	0.208	3.479
Overall vacation cost per person	-0.0019	-10.594	-0.0007	-3.346	-0.0006	-3.477
Door-to-door travel time	-0.070	-7.001	-0.057	-3.337	-0.093	-9.029
Route known for schedule disruption with adequate compensation	-0.240	-3.236	-2.570	-15.860	-0.253	-2.659
Route known for schedule disruption with inadequate compensation	-3.306	-13.903	-4.446	-13.795	-0.315	-2.891
Class probability	0.454		0.300		0.246	
Class membership						
Constant	0.199	0.374	-1.665	-2.806	0	
Age	0.008	0.835	0.033	3.270	0.00	
Adjusted ρ^2	0.127					
AIC	5769.752					
BIC	5839.458					

Table 8. Destination attractiveness rating linear regression results per class

	Class 1		**Class 2**		**Class 3**	
Class size	N=207		N=136		N=103	
	Parameter	t-ratio	Parameter	t-ratio	Parameter	t-ratio
Intercept	4.887	27.874	5.077	19.571	5.170	17.747
The destination is famous for…						
Enjoying nature	-0.088	-0.745	-0.245	-1.389	-0.059	-0.305
Exploring culture and social aspects	-0.018	-0.148	-0.339	-1.949	-0.297	-1.532
Relaxing vacation	*0.105*		*0.584*		*0.356*	
Destination familiarity						
Visited before	0.186	1.561	0.204	1.160	0.034	0.172
Heard about from others	0.034	0.292	-0.002	-0.010	-0.020	-0.102
Relatively unknown	*-0.220*		*-0.202*		*-0.014*	
Temperature range						
18°C - 24°C	0.315	2.682	0.596	3.379	0.757	3.895
24°C - 30°C	0.594	4.994	0.602	3.461	0.929	4.798
30°C - 36°C	*-0.910*		*-1.198*		*-1.687*	
Cost levels for staying at destination relative to the Netherlands						
45% lower	1.007	8.491	0.663	3.824	0.873	4.542
15% lower	0.883	7.455	0.812	4.637	0.922	0.195
15% higher	*-1.890*		*-1.476*		*-1.794*	
Positionality of destination compared to destinations of friends, family or other people you know well						
More attractive	0.788	6.639	0.433	2.492	0.538	2.797
Equally attractive	0.642	5.487	0.555	3.148	0.344	1.783
Less attractive	*-1.430*		*-0.988*		*-0.882*	
Prearrangements required to travel to destination						
No action required	0.620	5.223	0.562	3.238	-0.049	-0.256
1 action	0.261	2.200	0.451	2.574	0.184	0.946
Multiple actions	*-0.881*		*-1.014*		*-0.135*	
Observations	1242		816		618	
R^2	0.134		0.080		0.098	
Adjusted R^2	0.126		0.066		0.080	

Class 1: Value destination hunters

Class 1 is the largest class with a class share of 45 percent. We consider this class 'value destination hunters' as members of this class are the most sensitive to both cost and destination attractiveness. However, they are more sensitive to destination attractiveness than cost resulting in the highest WTP for more attractive destinations (around €529) among the three classes. The intercept also demonstrates that they are the most critical in their evaluation of destination attractiveness. While *value destination hunters* show sensitivity to travel time similar to that of

the entire sample, their WTP to travel to a destination with one hour less travel time is €37, due to their high sensitivity to cost. They are also the most tolerant to schedule disruptions as long as the disruptions are adequately handled. However, they display strong dislike for risk of inadequately handled schedule disruptions, although not the strongest among the three classes. Their sensitivity to cost is also reflected in their destination preference. For *value destination hunters*, the lower the cost of living, the higher the destination attractiveness. Higher cost of living decreases destination attractiveness by 1.89 points relative to the average attractiveness level shown by the intercept. *Value destination hunters* are also the most sensitive to positionality of destinations with all three levels of positionality being the strongest among the three classes.

Class 2: Risk minimizers

The second class accounts for approximately 30 percent of the sample. The defining characteristics of this class are their strong avoidance of schedule disruptions (Table 7) and stronger preferences towards destinations with relatively high per capita income over destinations with noticeably lower per capita income compared to the Netherlands (Table 8). Accordingly, we label this class *risk minimizers.* While they are the most tolerant to longer travel times, they show great dislike for schedule disruptions and inadequate handling of disruptions suggesting that they don't mind long journeys as long as there isn't a high risk of schedule disruptions. Interestingly, the parameter for destination attractiveness is not statistically significant, showing that other attributes characterize this class. Older travelers have a higher likelihood of belonging to this class, showing correlation between age and tendency to minimize risk. In terms of destination attractiveness, *risk minimizers* show stronger preference towards destinations with slightly lower cost of living more than destinations with much lower cost of living, indicating that they prefer developed regions. In addition, *risk minimizers* are the most likely to avoid destinations where prearrangements require multiple actions. Although not as much as *value destination hunters*, *risk minimizers* share a dislike for vacation destinations that are less attractive than those that their peers have traveled to. What is interesting however, is that risk minimizers rate destinations that are equally attractive as the vacation destinations of their peers over those that are more attractive.

Class 3: Travel time minimizers

Class 3 is the smallest class accounting for approximately 25 percent of the sample. Class 3 is the most sensitive to travel time and the least sensitive to the overall cost of vacations. Their WTP to spend their vacations at a destination with shorter travel time is the highest at €156 per hour. What is interesting is that they do not display strong patterns in preferences towards vacation destination characteristics. Therefore we label the third class 'travel time minimizers'. Risk of schedule disruptions has significantly lower contribution to utility compared to other classes with little difference between whether the disruptions are handled adequately or not. Destination attractiveness has lower significance to class 3 with a WTP value of €347 for a destination for one level higher attractiveness compared to €485 of the entire sample. Younger travelers within the sample are likely to belong to this class. As explained in section 3.2, only younger travelers with higher income sufficient for pure leisure travel are likely to be present in the sample. Younger travelers with high paying jobs may have more pressures at work making them sensitive to travel time and returning to work on time, but less concerned about

compensation for schedule disruptions. From the destination attractiveness regression analysis, we can see that the destination characteristic that does matter for *travel time minimizers* is temperature, being the most sensitive to temperature. While the class displays preference towards destinations with very low cost of living and higher positionality, the parameters for other levels of the two attributes are not statistically significant. Furthermore, parameters for the attribute 'prearrangements' are not statistically significant.

The three classes demonstrate that PAA levels can vary across travelers due to their heterogeneous preferences. The differences in preferences across the three class are substantial. Not only do the parameters of attributes vary, but the attributes that define the classes are also different. For example, while destination attractiveness has strong influence on PAA of *value destination hunters, risk minimizers* do not display statistically significant preferences regarding destination attractiveness. There are also commonalities however, such as the strong dislike for very hot temperatures, destinations with cost of living levels higher than the Netherlands and the absence of patterns in preferences regarding destination type and familiarity across all three classes.

In terms of policy planning, heterogeneity in preferences of leisure travelers indicate that policy measures can have uneven effects on PAA across travelers. By observing heterogeneity, policy makers can anticipate which class of travelers may be burdened the most with adverse effects from policy changes and formulate additional measures to compensate for that class. Furthermore, the parameters from segmented classes provide information for more effective planning. Taking destination attractiveness as an example, the overall sample shows a parameter value of 0.436 while *value destination hunters,* the largest class, shows a parameter value more than twice as large. In policy planning, accounting for heterogeneity enables policymakers to more accurately identify which traveler segments to target and how best to design interventions for them.

4.5. Implications for hypothetical aviation climate policies

As explained in the introduction, growth in air travel demand has outperformed technological improvements in aviation resulting in increase in emissions from the air transportation sector. Currently, the International Civil Aviation Organization's (ICAO) Carbon Offsetting and Reduction Scheme for International Aviation (CORSIA) sets 2019 emissions level as the baseline without absolute emissions reduction targets. Grewe et al. (2021) suggest that the CORSIA may not be sufficient to meet climate targets of the Paris Agreement. Recognizing the need for more ambitious air transportation climate impact mitigation measures, we discuss how more stringent hypothetical carbon offsetting measures may affect PAA of leisure air travelers and implications for measures that can motivate behavioral change.

We start by discussing the implications of assigning full carbon allowance purchase obligations to flights on PAA, using a conservative carbon allowance price level on a long-distance vacation route. Existing studies show mixed results regarding price elasticities in leisure air travel. Some studies suggest that demand for air travel is inelastic and charging for carbon allowance costs would have marginal effects on demand (Tol, 2007; Mayor and Tol, 2010; Pentelow and Scott, 2011). To the best of our knowledge, the highest documented price for carbon allowance in a

major compliance market was in the European Union Emissions Trading System (EU ETS), where in February 2023 the benchmark EUA contract traded as high as about €101.16/tCO_2e (Hatherick, 2023). We use a prudent upper-bound price level of €110/tCO_2e on one of the most popular vacation routes, the Amsterdam to Mexico City route, as an example to observe the degree of impact of applying full emissions offset credits to economy seats on PAA. Mexico and the Netherlands do not have substantial business ties (Statistics Netherlands [CBS], 2025) and only a small portion of the migrant population in the Netherlands have South American backgrounds (Statistics Netherlands [CBS], 2026), making it less likely to be a business or VFR destination. Mexico ranked nineth and Mexico City ranked 13th in terms of passenger volume from Schiphol airport in 2024 (Schiphol Group, 2024). The typical emission for the route is 574.1kg CO_2e per economy class seat (Google, n.d.). With return trip emissions amounting to 1148.2 kg CO_2e, the cost of a vacation in Mexico would increase by around €126 per person. This amount is equivalent to a 0.24 decrease in destination attractiveness level on a ten-point scale for *value destination hunters*, and a 0.36 point decrease for *travel time minimizers.* In comparison, the WTP to visit a destination with one level higher attractiveness is around €527 for *value destination hunters* and €347 for *travel time minimizers*. Although there is a decrease in PAA, the increase in cost is not sufficient to motivate many travelers to seek destinations with one level lower attractiveness. Note that that the attractiveness levels may not be perceived as discrete levels in the real world and a decrease smaller than one unit might induce some behavioral change due to such a policy. Furthermore, it must also be noted that behavioral change could result in carbon leakage if leisure travelers shift to making more frequent trips to closer destinations, reducing the overall environmental effectiveness. To adequately inform policy making processes, a comprehensive assessment of international tourism flows, destination substitution, and emissions across the tourism system would be needed.

This example suggests that to motivate substantial behavioral change, much higher carbon taxes may need to be implemented to leisure air travel. Accordingly, more ambitious options such as credits from direct air carbon capture and sequestration (DACCS), which often command prices more than €500 per ton (Regreener, 2025), may be considered. DACCS credits are not yet widely used in major compliance markets but are based on the actual amount of technology-based carbon removal from the atmosphere. In addition to its potential effectiveness for behavioral intervention, the use of credits that remove carbon from the atmosphere in market-based measures may further contribute to long term preservation of the social value of international mobility and leisure air travel by making leisure travel more sustainable. With high credit prices and lack of consensus in non-carbon climate effects of aviation, the most feasible step would be to apply such high-cost credits only to carbon emissions from flights. If overall vacation costs would increase due to the addition of high carbon prices, PAA of vacation destinations may decrease substantially. Travelers who find substitute destinations with comparable attractiveness, and cost of stay and activities accessible by shorter flights may opt for such destinations, as an increase in overall vacation cost would be lower due to less fuel burn on shorter flights. Those who cannot find substitute destinations worth visiting for the increased vacation cost may perceive vacation travel by air to be inaccessible. The class with the highest impact on PAA would be *value destination hunters* due to their high sensitivity to cost. For *travel time minimizers*, a knock-on effect of high carbon prices can lead to additional motivation for behavioral change as airlines may operate flights at lower speeds to reduce fuel consumption, increasing travel time (Edwards et al., 2016; Sobieralski, 2023).

The loss in utility due to (high) price increases, however, may be smaller in the broader context of PAA compared to estimates from frameworks focused only on transportation aspects. First, as our results show, destination choice is to some extent subject to positionality. As price increases will result in many travelers choosing a nearer by destinations or not to fly at all, the resulting decrease in PAA would be smaller than estimated in models that do not account for positionality. Secondly, if DACCS credits are implemented, successful behavioral intervention becomes less urgent as carbon from the atmosphere equivalent to carbon emissions from flights shall be re-captured. Under such a scenario, policy makers can implement measures to compensate for the decrease in PAA thereby mitigating adverse impacts on international mobility. For all three classes, improving on-time performance of flight schedules and setting strict standards for schedule disruption handling by airlines and airports may fully compensate for the decrease in PAA levels on routes prone to schedule disruptions, considering that all three classes are very sensitive to schedule disruptions and handling. Negotiating tourism visa exemptions can also reduce prearrangements for travel, increasing attractiveness of destinations that require multiple actions, and consequently increasing PAA levels. In particular, while *value destination hunters* will be most affected by the cost increase due to their high cost sensitivity, negotiating tourism visa exemptions with lower developed countries (LDCs) is likely to mitigate the impact on PAA for this class the most as they prefer destinations with very low cost of living. LDCs are also destinations that often require more prearrangements due to vaccination requirements. In addition, this can contribute to maintaining tourism flow to LDCs, particularly to regions where tourism is crucial for economic development (Peeters and Eijgelaar, 2014).

4.6. Conclusions

This study aimed to estimate the effects of PAA determinants for leisure air travelers in the Netherlands and discuss how hypothetical air transportation emissions offsetting policies may affect PAA of leisure travelers through PAA determinants. We focus on leisure air travel, as it is the most non-essential travel purpose by air with the most flexibility for substituting destinations, making it the most suitable target for behavioral intervention policies or more stringent emissions offset obligations. Using LCCM on stated choice data for a two-week vacation, we observed three latent classes within people in the Netherlands who had experience of traveling solely for leisure within the past three years, and the preferences towards PAA determinants of each of the three classes. Destination attractiveness was included as an attribute in the stated choice experiment to observe trade-off with attributes related to impedance. A separate destination rating experiment was added with destination attractiveness as the dependent variable to understand how destination characteristics determined attractiveness. Linear regression was performed on destination rating data for the overall sample, and for each class identified through LCCM to observe how destination characteristics influence destination attractiveness. The results reveal three classes of travelers, one prioritizing cost and value of vacations, another prioritizing low risk, and the last prioritizing travel time, confirming heterogeneity in preferences regarding PAA within leisure travelers.

Assessing the impact of hypothetical air transportation climate policy on leisure air travelers' PAA, we conclude that climate measures much more stringent than ICAO's CORSIA may be feasible without severely impacting PAA of leisure air travelers. Even if all carbon emissions

from leisure air travel are required to be offset based on prudent carbon allowance prices, the effect on PAA of leisure air travelers may be marginal and insufficient for significant behavioral change. For behavioral intervention, more ambitious options, such as applying DACCS credits for one-to-one removal of carbon emissions from leisure air travel, may be needed considering leisure travelers' high WTP to visit more attractive destinations. If measures that remove flight emissions are implemented, policy makers can implement additional measures to compensate for the decrease in PAA to some degree. We observe that improving flight schedule reliability where needed, or increasing attractiveness of destinations through efforts to reduce prearrangement processes required for entering vacation destination countries can increase PAA. Furthermore, we observe that vacation destinations are subject to positionality. Our observations regarding positionality of vacation destinations suggest that if behavioral interventions are successful and vacationing at long-haul flight destinations become less common, the utility loss from giving up a vacation at a long distance destination may be smaller than conventional estimations that do not account for positionality.

While this study reveals insights relevant for behavioral change and behavioral implications from market-based aviation climate measures from a PAA perspective, the overall benefits and drawbacks of behavioral change and carbon offsetting in leisure air travel were not included in the scope of this study. In particular, air transportation plays a major role in sustaining economies heavily reliant on tourism (Koo and Lau, 2019; Chow et al., 2021; Vergori and Arima, 2022) and regions with low air connectivity may suffer substantial adverse economic impact if a decrease in inbound tourists leads to a knock-on effect of airlines cancelling their routes. Mature studies need to be carried out focusing on the overall effect of behavioral change and carbon offsetting on economic distributional effects from leisure air travel, the air transportation sector, and climate impact mitigation in the international tourism industry.

As this was the first attempt to quantify travelers' preferences towards PAA determinants, there were limitations to the study. Although discrete choice modeling can be used to quantify PAA levels using the logsum of choice sets, with insufficient knowledge in the literature regarding the effects of PAA determinants, it was not possible to anticipate consideration sets of vacation destinations that could be used to design a realistic experiment. Therefore, we aimed at observing the determinants and heterogeneity of air travelers rather than measuring PAA levels. Future studies may aim to use the logsum to estimate PAA levels for real-world destinations. To make this feasible, however, the theoretical scope of accessibility may need to be narrowed further—for example, by focusing on specific destination types, such as beach destinations, cultural tourism destinations or mountain getaway destinations—to form consideration sets feasible for research. Future studies may also consider designing choice sets that include competing modes, such as high-speed rail, to examine perceived accessibility across different transport modes and to identify opportunities for encouraging a shift toward more sustainable alternatives. While we focused on the big picture of PAA and strived to balance the focus on destination and transportation characteristics as much as possible, future studies more focused on the transportation aspect may specifically aim to reveal the influence of transfers on PAA. Some important transportation characteristics that could be considered are transfers and transportation costs.

The use of stated choice data to estimate the effect of PAA determinants is another limitation of this study. In real-world decision-making situations, influencing factors such as actual budget

constraints, risk perceptions, emotional influences or the influence of the opinions of travel companions may affect PAA of vacation destinations differently compared to the hypothetical choice situation of this study. Furthermore, several factors that may affect PAA were controlled in the hypothetical choice situation to design a feasible study. Of the four components of accessibility as defined by Geurs and van Wee (2004), the temporal component was fixed to the summer holiday period, and to a vacation duration of two weeks. Therefore, the effect of variations in the temporal component on PAA could not be observed. Travelers may have different preferences for activity types or temperatures depending on the season that they choose to take their vacations. The fact that the hypothetical choice situation implied a holiday in the summer holiday period, and that the survey was distributed in summer, may have also affected the temperature preferences of the respondents, as the Netherlands frequently have periods of high temperatures in the summer. Accordingly, there is a possibility that respondents may have preferred to escape hot temperatures during this period.

Finally, the context of our study excluded situations in which the vacation destination is extremely attractive, or the vacation options were not attractive enough. A study including destination attractiveness levels ranging from eight to ten may yield different parameters for all attributes, but potentially with less valid parameter values as choices of respondents may not be based on compensatory behavior. If policy goals are to motivate people to limit leisure air travel to only the destinations that each person finds extremely attractive, a separate study in this context would be needed. Furthermore, the hypothetical choice situations assumed that respondents would undertake a vacation by air and therefore did not include an opt-out alternative. Consequently, the estimated preferences should be interpreted as conditional on the decision to take an air vacation and do not capture situations in which travelers decide not to travel by air, stay at home, or substitute air travel with alternative modes of transportation. Future research could incorporate an opt-out alternative and expand destination attractiveness to investigate how changes in perceived air accessibility influence both vacation choice and the decision to undertake air travel in the first place.

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Chapter 5 Conclusions

5.1. Conclusions for accessibility theory

The findings of Chapter2 and Chapter 3 contribute to accessibility theory by identifying distinct characteristics of accessibility and accessibility research in long-distance air travel context. Depending on the research objective, AAT can be viewed as either comparable to general accessibility or fundamentally distinct. The two can be considered comparable in that conventional connectivity-based and gravity-based accessibility measures can be applied to AAT in a manner similar to local or regional contexts. However, AAT becomes distinct when the individual component of accessibility is considered. Applicability of conventional person-based measures based on the space-time prism of Hägerstrand (1970) is limited to daily accessibility of short-haul flight trips. In the context of accessibility by air transportation (AAT), travel costs may become prohibitive rather than merely unattractive. High and volatile airfares, along with the low frequency of trips by air transportation compared to other transport modes, encourage travelers to make deliberate, trip-specific decisions rather than rely on habitual behavior. Moreover, long travel times and the effort associated with air travel can give rise to preferences that appear counterintuitive in general accessibility contexts—for example, results from Chapter 3 demonstrate that some travelers may prefer longer travel times that allow for rest or sleep over very short trips. In terms of how travelers view air transportation, it is considered a transport mode with no limit to the access it provides, allowing travelers to access any location around the world as long as they prepare for the trip in terms of time, finances and the required effort to travel. Furthermore, for mid-haul and long-haul air travel, flexibility in the journey is extremely low as there is often no alternative transport mode, and modifying itineraries can be very costly. As a result, incorporating the individual component highlights that AAT differs from general accessibility not only in scale, but also in the nature of traveler behavior and decision-making. Heavily adopting the individual component to AAT contributes

to accessibility assessments that can closely represent accessibility as perceived by air travelers. This leads to a conclusion that while conventional connectivity-based or gravity-based accessibility measures can be used with marginal adaptation to the air travel context, research regarding perceived accessibility by air transportation (PAA) requires attention to specific characteristics of air travel.

5.2. Empirical contributions for PAA

To fill the knowledge gaps identified in the literature review study, two empirical studies regarding PAA have been conducted. The focus group study reveals that the importance attached to air travel varies significantly across individuals. This is further supported by the findings of Chapter 4, which identifies distinct segments within a sample of leisure air travelers with differing sensitivities to cost, travel time, and destination attractiveness. Two classes of air travelers, consisting of around 55 percent of the sample combined, displayed preferences towards PAA determinants noticeably different from those of the aggregate sample. These findings highlight the limitations of aggregate approaches and underscore the need to account for heterogeneity in accessibility assessments.

What is noteworthy is that uncertainty emerges as a key determinant of PAA. The COVID-19 pandemic illustrated how uncertainty related to travel restrictions, boarding procedures, and border controls can strongly influence individuals' willingness to travel. According to observations from the focus group meeting study in Chapter 3, the main deterring factor for avoiding air travel during the pandemic period was revealed to be the uncertainty of being denied boarding at the airport due to positive COVID-19 test results, and the uncertainty of receiving insurance claims rather than risk of infection. Even outside such exceptional circumstances, the possibility of delays, cancellations, or disruptions plays an important role in shaping PAA. This suggests that reliability and predictability are central components of accessibility in the air transport context. Specifically, results from Chapter 4 reveal that the possibility of schedule disruptions can significantly lower PAA, to a degree that some travelers may opt for less attractive vacation destinations if the route is known to have higher schedule reliability.

Additionally, the findings emphasize the importance of systematically identifying and measuring the determinants of PAA. While some determinants can be directly elicited from travelers—such as cost or travel time—others, such as positionality (the level to which the value of a good is influenced by the consumption behavior of others), may not be explicitly recognized but nonetheless exert a noticeable influence on PAA. Moreover, because perceptions regarding AAT may differ across individuals with different socio-demographic characteristics, cultural context, and prior experiences, the determinants of PAA are likely to be context-dependent. In this thesis, the influence of positionality on PAA was tested based on the literature (Van Wee, 2021; Van Wee and Mokhtarian, 2025; Molin et al., in press). Whether there may be other latent factors specific to groups of travelers with different backgrounds remains unknown. This underscores the need for further exploring potential latent factors of PAA and empirical approaches that capture both observable and latent factors influencing PAA.

Next the generalizability of the results of this thesis is discussed. First, although the two studies on PAA in this thesis were conducted in the Netherlands, the results of this study may be applicable to air travelers around the world to a large extent as air travel generally requires individuals—regardless of where they live—to have an income above a certain level or an occupation that involves long-distance travel. Such income levels and occupation characteristics are applicable to many people in OECD countries and probably even beyond. Secondly, the methods used in this thesis demonstrate how the individual component of accessibility can be incorporated into PAA research. The approach can be used for PAA research in other regions with different geographical or cultural contexts. There are, however, contributing factors to PAA that may vary across different national or regional contexts. For developing nations, typical air travel frequency may be significantly lower compared to developed countries and each trip using flights may be considered more of a luxury activity of the affluent class, resulting in different contributions of the positionality effect. Thirdly, national border characteristics may also contribute to different levels of dependence on air travel for long-distance travel as island states or countries with borders that cannot be crossed through other means of transport may have to rely on flying to travel beyond national borders.

5.3. Implications of results for aviation climate policies

Given the absence of commercially viable zero-emission aviation technologies in the next two or so decades, various approaches for mitigating the climate impact of aviation need to be considered. This thesis provides insights into how market-based aviation climate measures may affect PAA. By measuring the importance of PAA determinants, potential impact of cost increases due to market-based climate measures on PAA, relative to the importance of other PAA determinants is observed. Furthermore, the feasibility of more ambitious market-based measures for targeting effective behavioral change from a PAA viewpoint is discussed, along with opportunities for compensating for the loss in PAA levels if high-cost carbon credits are to be adopted in a market-based measure for substantial offsetting of aviation greenhouse gas emissions.

A key finding is that the importance of activities accessed by air travel varies substantially across individuals. From a PAA perspective, maintaining accessibility to essential activities is critical, while less essential activities may be more amenable to policy intervention. Leisure travel emerges as the most expendable and substitutable purpose of air travel, making it a suitable target for behavioral intervention. It is substitutable both in terms of activity type and destination, as some travelers may opt for alternative forms of recreation or choose destinations that are closer or reachable by other modes. It must be noted that there may be travelers that specifically seek long-distance vacation destinations to experience different cultures. Around 40 percent of the air travelers that participated in the study in Chapter 4 stated that the most frequently pursued vacation activity using air travel is ‘exploring culture and social aspects’. Those who fly long-distances to visit destinations with great cultural distances contribute to substantial climate impact from flying. However, no meaningful patterns in preferences towards aspects of flying were observed based on vacation activity preferences. Findings from the focus group study in Chapter 3 demonstrate that the activities pursued through business air travel also varied in importance. The importance of the activity varied depending on the type of activity, with some individuals stating that certain activities are substitutable through online means and

others stating that online means were not sufficient for substituting business activities. The importance of business travel itself varied across individuals as well with some travelers stating that they would find a new occupation if they're jobs would not involve traveling long distances by flight anymore. Business destination substitutability may require a thorough exploration of alternative options, and an analysis of related costs and benefits and accordingly, longer time to choose alternative destinations compared to leisure travel.

Visiting relatives, on the other hand, was identified as a considerably more important activity accessed by air travel. Focus group discussions revealed that online interactions do not sufficiently replace interactions in person. Furthermore, in some cases there is no flexibility in destination choice, and accordingly in mode choice, reducing options to change destinations and travel modes as a response to policy interventions. Moreover, visiting relatives was identified as an activity with significant implications for individuals' quality of life. Notably, while the air travel purpose category as defined by the World Tourism Organization (2018) ties visiting 'friends or relatives' into a single category, the results from Chapter 3 indicate that only visiting relatives constitutes the core of essential travel in this category.

The findings lead to the conclusion that targeting behavioral intervention in leisure air travel or targeting absolute reduction of aviation climate impact through carbon credit purchase are pathways for offsetting aviation climate impact without substantial impact on PAA. Among various tools for behavioral interventions and carbon offsetting, this thesis focused on market-based measures and the potential effect of different levels of carbon prices. The results from this thesis demonstrate that mandating full offset of flight emissions at historic high carbon prices in compliance markets may have marginal effectiveness for behavioral intervention for leisure air travelers. Carbon prices that far exceed historic price levels in compliance markets would be needed for successful behavioral intervention. Because market-based measures that meaningfully reduce flight frequency or distance require substantial cost increases, policymakers could instead leverage these high price levels to achieve direct mitigation by mandating the use of carbon removal or avoidance credits, rather than relying on conventional compliance allowances.

Based on the results of this thesis, policy recommendations are provided for market-based aviation climate measures. First, from a PAA viewpoint, it may be feasible to target full flight carbon emissions offsetting rather than carbon neutral growth from a baseline year or partial emissions offsetting for leisure air travel. Carbon credits from United Nations Framework Convention on Climate Change's (UNFCCC's) 'Reducing Emissions from Deforestation and Forest Degradation in Developing Countries Plus' (REDD Plus) framework can be considered as a good starting point as credit prices are relatively low with room for price hikes due to increased demand from the air transportation sector purchasing credits to fully offset its carbon emissions. Although there are concerns regarding the quality of REDD plus credits (Yang and Park, 2025), they do not rely on baseline allowance allocations and can provide co-benefits for biodiversity (Mishra, 2026). At this stage, however, further behavioral interventions need to be pursued in parallel to market-based measures, for example, by improving schedule reliability of alternative long-distance transport modes or developing local vacation destinations that travelers find attractive. Parallel measures are necessary even if market-based measures reduce frequency and distance of leisure air travel, as a market-based measure based only on carbon

emissions offsetting will not offset the substantial non-CO_2 climate effects from aviation. In addition, exemptions from market-based measures for family-related air travel may be desirable to preserve access to essential activities. Furthermore, with quality concerns regarding REDD Plus credits, there is no guarantee that carbon emissions from the air transportation sector will actually be offset. A possible outcome may be that increased demand for REDD Plus credits leads to credit price increase to a level that induces behavioral change in leisure travelers. On the other hand, there is also the possibility of higher credit prices stimulating the development of additional REDD Plus projects. These additional projects however, will reduce the price increase due to an increase in the supply of credits.

Importantly, the findings suggest that the negative impact of high carbon costs on PAA can be partially mitigated by improvements in other determinants, such as travel convenience or destination attractiveness.

Furthermore, the results indicate that vacation destinations exhibit characteristics of positional goods, meaning that their value for a person partly depends on the choices of others. If long-distance travel becomes less common overall, the perceived loss in utility from not undertaking such trips may be lower than conventional estimates suggest. Taken together, these findings imply that moving towards carbon neutrality may be less detrimental to leisure travelers' PAA than often assumed.

At the same time, exemptions to market-based measures would be required to avoid strong negative impact on PAA of travelers pursuing activities with high importance and low substitutability, namely visiting relatives as identified in Chapter 3. Residency documents can be used to confirm visits to relatives and approve carbon credit purchase exemptions with limited frequency. This may be achieved, for example, by granting travelers flying to visit relatives the option to apply for emissions charge refunds to the regulatory body that manages aviation emissions charges.

For business air travel, full carbon emissions offsetting would have limited effect on PAA of business travelers as airfare is paid by the employers. Rather, the cost increase may affect the decision of firms, encouraging them to reduce lower-value trips. Individuals that may be affected in terms of PAA are those that combine business trips with leisure activities, or those who personally attach high value to business trips.

As carbon credit prices can fluctuate with market-based measures, carbon credit price trends, and changes in PAA and aviation emissions require monitoring, followed by periodic adjustments to the market-based measure. If credit prices are to remain at levels insufficient for behavioral change, additional policy measures could be introduced. One option would be to expand offsetting requirements to non-CO_2 effects of aviation if a scientific consensus regarding the average climate effects of non-CO_2 emissions effects in CO_2 per ton equivalent is reached at the time of periodic adjustments. Another option could be to reduce the market-based measure exemptions for air travel for visiting relatives. A third option would be to replace the carbon credit used for offsetting emissions to higher cost carbon credits with guaranteed carbon removal from the atmosphere, such as direct air carbon capture and sequestration (DACCS) credits. For all three options, the results of this thesis provide insights relevant to anticipating how more stringent market-based aviation climate measures may affect PAA of air travelers.

5.4. Avenues for future research

This thesis opens several avenues for future research.

First, further refinement of methods for measuring PAA is needed. Narrowing the scope of analysis—for example by focusing on specific types of holidays such as beach tourism or cultural travel—may allow for more detailed and realistic choice experiments and improve the precision of estimated preferences. A major challenge in designing a utility-based study for PAA is rooted in the fact that air transportation serves a large number of destinations, making it difficult to form considerations sets for choice alternatives. A narrower scope can open up the possibility of creating a realistic, yet feasible consideration set to measure PAA using the logsum in a utility-based approach to PAA. From a policy standpoint, results from such a study may provide insights specific policy recommendations for behavioral intervention aimed at motivating air travelers to visit destinations that serve the same purpose, but with shorter flight distances.

Second, future research should examine PAA in different geographical and socio-economic contexts. Variations in national average income levels, infrastructure, and geographic characteristics—such as island or landlocked settings—may influence PAA. Whether these differences have meaningful contributions to PAA, or whether more conventional attributes of transportation dominate in terms of influence on PAA is currently unknown. Comparative studies across countries would enhance the generalizability of findings.

Third, studies aiming to quantify the perceived importance of different activities accessible by air travel can be used to design policies that lead to more equitable distributions of aviation climate impact offsetting obligations. This thesis revealed that in terms of PAA, visiting relatives ranks higher in importance compared to leisure, or visiting friends. However, to what degree the importance of such activities differ is not known. A choice experiment can be designed with the activity included as an attribute among other PAA determinants. Using a sample of potential air travelers with relatives living in destinations accessible by flight, the importance of activities accessed by air can be measured. Such a study may provide actionable insights into how aviation climate impact offsetting obligations can be distributed across different travel purposes.

Fourth, expanding the analysis to include competing long-distance transport modes, such as high-speed rail, would provide a more comprehensive understanding of perceived accessibility of long-distance destinations. This is particularly relevant in regions where modal substitution may play a significant role in reducing aviation emissions.

Fifth, further research is needed on the role of social dynamics and positionality in shaping travel behavior. The increasing influence of social media may amplify positional effects by shaping perceptions of desirable destinations and travel experiences. Understanding these dynamics could provide valuable insights into how travel demand evolves and how it may respond to policy interventions.

Finally, a topic that has received little attention in this thesis, but that is relevant for climate policy is business AAT. First, the types of business activities and the level of necessity of activities, as well as the elements of the transport component of accessibility specific to business

travel decisions need to be explored to identify measures that can motivate businesses to reduce non-essential business travel by flight. Secondly, the carbon footprint of business class seats is substantially higher than economy class seats as larger spaces in aircraft cabins are allocated to business class seats with very relaxed or no check-in luggage weight limitations.

5.5. Concluding remarks

This thesis has demonstrated the value of adopting a PAA perspective in the study of air transportation and its environmental impacts. By integrating behavioral insights with accessibility theory, it provides a more comprehensive understanding of how air travelers evaluate and respond to changes in the air transport system.

As the aviation sector faces increasing pressure to reduce its environmental footprint, such insights are essential for designing policies that are both effective and socially acceptable. By identifying the determinants of PAA and their relative importance, this thesis contributes to a more nuanced understanding of how more ambitious climate policies may affect air traveler behavior and their access to desired activities and opportunities located at great distances. Incorporating PAA into aviation climate policy evaluation may require considerable research from different regions around the world. However, the literature review study (Chapter 2) reveals that accessibility research has been limited by data availability and modeling restrictions. With constant development in information technology and resulting data availability and enhanced modeling capabilities, it may be feasible to adopt PAA for planning aviation climate policies tailored to different regions around the world.

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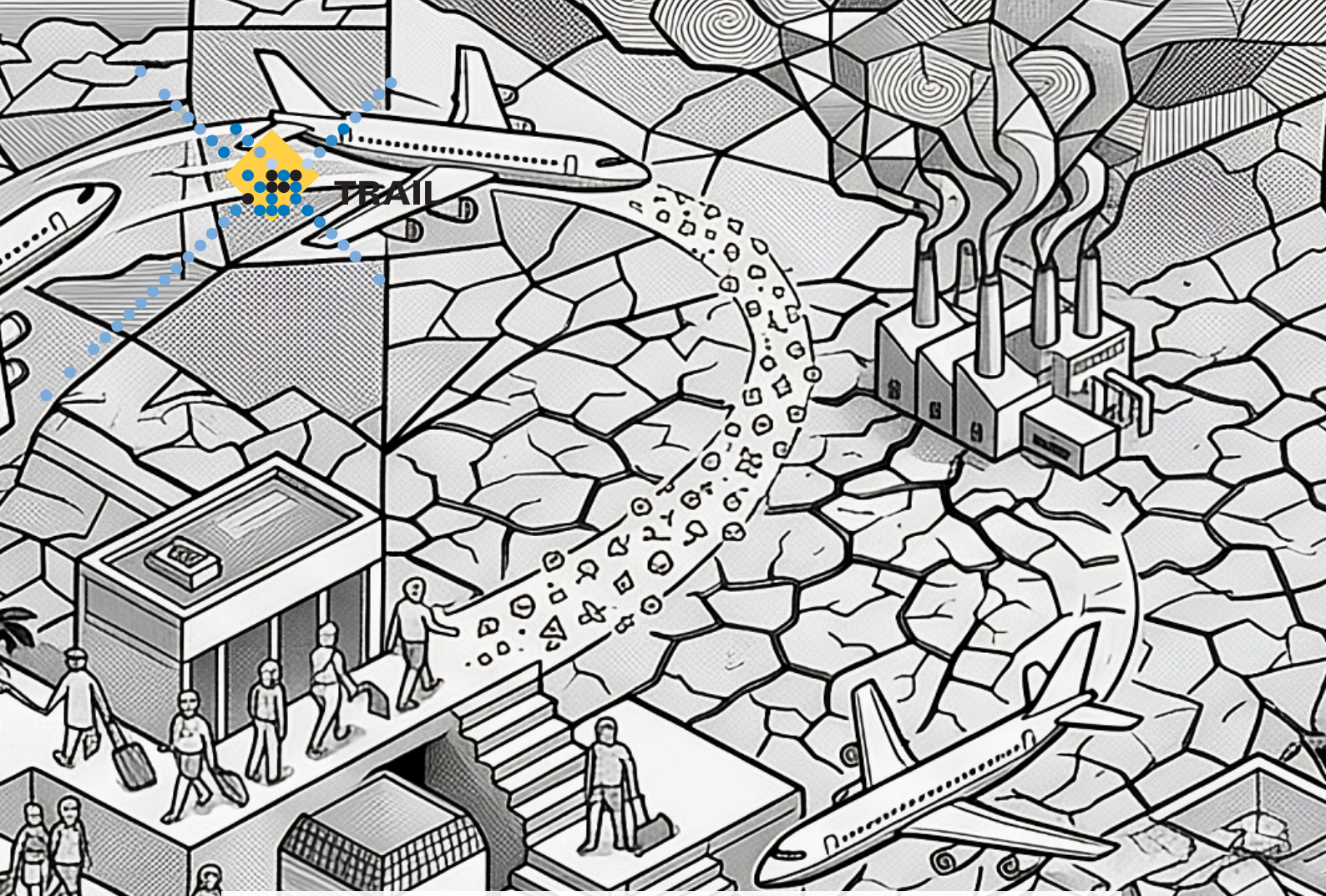

Summary

This thesis investigates the determinants of perceived accessibility by air (PAA) for leisure air travelers in the Netherlands. Through a literature review, focus group study, destination-attractiveness ratings, and discrete choice models, it studies the effects of destination and transport attributes and identifies heterogeneous traveler segments. The findings provide insights into how market-based aviation climate policies may affect leisure air travel behavior and PAA of vacations.

About the Author

Sihyun Yoo is a researcher specializing in perceived long-distance accessibility. His research focuses on traveler behavior and preferences, transportation climate policy, and behavioral interventions using qualitative methods and discrete choice modeling to understand how climate measures affect perceived accessibility.

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