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Long distance accessibility by air transportation: a literature review

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ABSTRACT

Air transportation is a mode of transport developed specifically to provide access to long-distance destinations that may otherwise be infeasible or at least more difficult to reach. Accordingly, there are distinct aspects of air travel that require consideration when assessing accessibility by air transportation, which are not addressed in general local accessibility studies. This paper reviews studies of accessibility by air transportation. The studies in question were published in academic journals, and we analysed them using the broad theoretical framework of accessibility of Geurs and van Wee [Accessibility evaluation of land-use and transport strategies: Review and research directions. *Journal of Transport Geography*, 12(2), 127–140]. We discuss the characteristics of accessibility by air transportation to consider when designing research, as well as trends and knowledge gaps in the existing literature. An important gap is that, while there is a growing interest towards perceived accessibility by air transportation, accessibility measures based on this perspective have not yet been applied yet. Additionally, the literature is largely focused on the transport and land-use components of accessibility as opposed to the individual and temporal components. We finish by discussing the benefits and drawbacks of directly applying conventional accessibility measures for research on accessibility by air transportation, as well as options to modify the temporal component of conventional person-based accessibility measures for better applicability in the air travel context.

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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

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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 (Boisjoly & El-Geneidy, 2017; Bruinsma & Rietveld, 1998; Geurs & van Wee, 2004; Handy, 1996; Neutens et al., 2011; Patterson & Farber, 2015), there are distinct characteristics of air travel that are not considered in general accessibility research. These characteristics include:

- Relatively high generalised travel costs (GTC) (at least travel times and travel costs, relative to most other trips).
- Air travellers 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 travellers, 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 travellers’ 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 and 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 and 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 and 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 (operationalisation 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 conceptualised for research. Some studies conceptualised 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 and van Wee (2004) are discussed in the context of AAT, followed by a description of methods used to collect and review literature in Section 3. Findings from the literature review are presented in Section 4, answering RQs A, B, C, and D. Section 5 discusses answers to RQs E, F, and G. Research gaps and avenues for future research (RQ H) are presented in Section 6, with concluding remarks in Section 7.

2. Accessibility theory

In this review, we analyse accessibility research in the collected literature based on the theoretical framework of Geurs and 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 and van Wee (2004), illustrates the comprehensive theoretical scope of accessibility and its potentially numerous contributing factors by organising 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

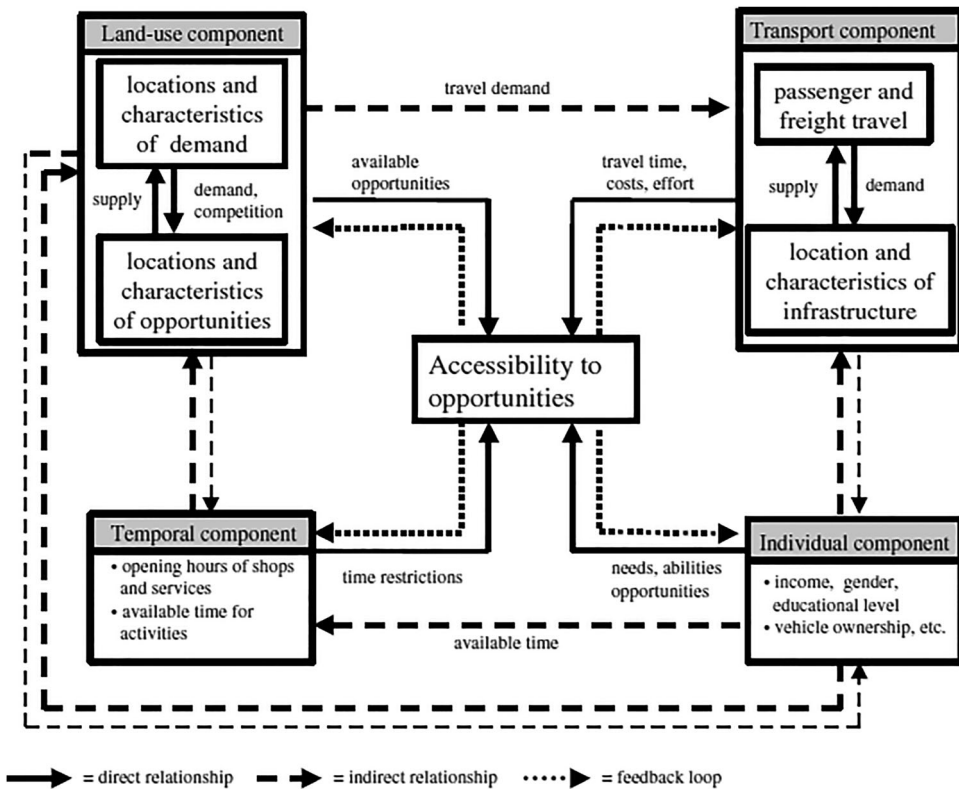


Figure 1. Relationships among accessibility and its components (Geurs & van Wee, 2004).

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 minimise confusion.

Figure 1 also illustrates the relationships among accessibility components and accessibility itself. In addition to direct relationships, Geurs and 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 materialise (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 materialise 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 traveller has experienced any change in accessibility levels.

In addition to the accessibility components and their interactions, Geurs and 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 modelling 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.

3. Methodology

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 finalised on January 19, 2023, with a total of 44 papers collected for review. The process of literature collection is depicted in Figure 2.

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 traveller, 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

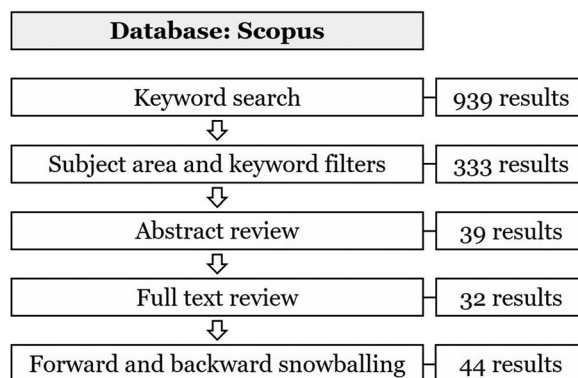


Figure 2. Literature collection process and number of results per each step.

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.

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

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

Reference	Transportation mode	Geographical scope
Toh (1984)	Air	International
Irwin and Kasarda (1991)	Air	U.S. domestic
Bruinsma and Rietveld (1993)	Air, road, rail	42 agglomerations in Europe
Chou (1993a)	Air	U.S. domestic
Chou (1993b)	Air	U.S. domestic
Shaw and Ivy (1994)	Air	U.S. domestic
Bruinsma and Rietveld (1998)	Multimodal	Europe
Bowen (2000)	Air	Southeast Asia, connected regions
Bowen (2002)	Air	Global
Macchiavelli and Vaghi (2003)	Air	Mediterranean basin region
Matthiessen (2004)	Air	Baltic Sea area
Reynolds-Feighan and McLay (2006)	Air	Global
Spiekermann and Wegener (2006)	Multimodal	Europe
Grubestic and Zook (2007)	Air	U.S. domestic
Yamaguchi (2007)	Air	Japan domestic
Hsu and Shih (2008)	Air	Global
Sellner and Nagl (2010)	Air	Austria, international
Halpern and Bräthen (2011)	Air	Norway domestic, international
Matisziw et al. (2012)	Air	U.S. domestic
Redondi et al. (2012)	Air	International
Banister and Givoni (2013)	HSR, multimodal	EU-27
Cao et al. (2013)	Air, HSR, rail	China
Hesse et al. (2013)	Air	EU-27
Mukkala and Tervo (2013)	Multimodal	Europe
Burghouwt and Redondi (2013)	Air	Europe
Redondi et al. (2013)	Air	Europe, international
Borodako and 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 and Reynolds-Feighan (2016)	Air, road	Ireland, international
Beria et al. (2017)	Multimodal	Italy, domestic
Park and O'Kelly (2017)	Air	U.S. domestic
Dai et al. (2018)	Air	Southeast Asia
Jose and Ram (2018)	Air	India, domestic
Laurino et al. (2019)	Air, car, bus, rail	Italy, domestic
Sun and Lin (2019)	Air	Global
Gibbons and Wu	Air	China domestic
Mueller and Aravazhi (2020)	Air	Scandinavian region, international
Mueller (2021)	Air	Europe, U.S. domestic
Avogadro et al. (2021)	Air, HSR	Europe
Bansal and Sen (2022)	Air	India
Liao et al. (2022)	Air	Hong Kong, China, international
Pot and Koster (2022)	Air	Europe

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 modelling 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.

4. Findings from literature review

4.1. Progression of AAT research approaches (RQ A)

We organised 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 categorising research approaches, we consider categorisation 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), generalisation of measures was necessary. Table 2 shows the timeline of published papers for each research

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 and Kasarda (1991)			
1993 Chou (1993a)	Bruinsma and Rietveld (1993)		
Chou (1993b)			
1994 Shaw and Ivy (1994)			
1998		Bruinsma and Rietveld (1998)	
2000 Bowen (2000)			
2002 Bowen (2002)			
2003 Macchiavelli and Vaghi (2003)			
2004		Matthiessen (2004)	
2006 Reynolds-Feighan and McLay (2006)	Spiekermann and Wegener (2006)		
2007 Grubestic and Zook (2007)			Yamaguchi (2007)
2008	Hsu and Shih (2008)		
2010			Sellner and Nagl (2010)
2011		Halpern and Bräthen (2011)	
2012 Matisziw et al. (2012)			
Redondi et al. (2012)			
2013 Burghouwt and Redondi (2013)	Cao et al. (2013)	Banister and Givoni (2013)	Redondi et al. (2013)
	Hesse et al. (2013)		Mukkala and Tervo (2013)
2014 Borodako and Rudnicki (2014)			
Sheard (2014)			
2015 Allroggen et al. (2015)			
2016	Cattaneo et al. (2016)		Vega and Reynolds-Feighan (2016)
2017	Beria et al. (2017)		Park and O'Kelly (2017)
			Laurino et al. (2019)
2018 Dai et al. (2018)			
Jose and Ram (2018)			
2019	Sun and Lin (2019)		
2020 Mueller and Aravazhi (2020)			Gibbons and Wu (2020)
2021 Mueller (2021)	Avogadro et al. (2021)		
2022 Bansal and Sen (2022)	Bansal and Sen (2022)		
Liao et al. (2022)	Pot and Koster (2022)		

Notes: Bold italic font: studies with perceived accessibility approach.

approach, with approaches based on the type of measures organised 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” (Chou, 1993a, 1993b; Irwin & Kasarda, 1991; Shaw & Ivy, 1994; Toh, 1984). Early connectivity-based approaches were based on the Shimmel index, which evaluates network performance using aggregate shortest path distances between all nodes in a network (Shimmel, 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 approach observed in literature was the qualitative research approach that explored broader scopes and details specific to AAT (Banister & Givoni, 2013; Halpern & Bråthen, 2011; Matthiessen, 2004). 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 (Sellner & Nagl, 2010; Yamaguchi, 2007), or methods that are not derived from connectivity-based nor gravity-based measures (Laurino et al., 2019; Park & O’Kelly, 2017; Redondi et al., 2013; Vega & Reynolds-Feighan, 2016). The final and most recent approach involved the adoption of elements related to perceived accessibility (Avogadro et al., 2021; Beria et al., 2017; Borodako & Rudnicki, 2014; Cattaneo et al., 2016; Halpern & Bråthen, 2011; Laurino et al., 2019; Mueller, 2021; Mueller & Aravazhi, 2020). To summarise 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 and Rietveld (1998). From 2007 onwards, several studies utilised 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).

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, 2021; Mueller & Aravazhi, 2020), 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 Shimbil 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 generalisation 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.

4.2. Research aims of AAT studies (RQ B)

We identified six broad categories of research aims into which the collected literature could be categorised (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 behaviour, and the extent to which land-use policies can influence accessibility beyond administrative borders.

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) travellers 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

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 and Ivy (1994) Bowen (2000) Bowen (2002) Hsu and Shih (2008) Matisziw et al. (2012) Burghouwt and Redondi (2013) Allroggen et al. (2015) Dai et al. (2018) Jose and Ram (2018) Bansal and Sen (2022)
Assess locational accessibility levels	Bruinsma and Rietveld (1993) Bruinsma and Rietveld (1998) Cao et al. (2013) Redondi et al. (2013) Hesse et al. (2013) Borodako and Rudnicki (2014) Vega and Reynolds-Feighan (2016) Beria et al. (2017) Laurino et al. (2019) Mueller (2021) Avogadro et al. (2021) Bansal and Sen (2022)
Examine relationships between accessibility and economic growth/regional development	Irwin and Kasarda (1991) Matthiessen (2004) Spiekermann and Wegener (2006) Yamaguchi (2007) Sellner and Nagl (2010) Mukkala and Tervo (2013) Sheard (2014) Cattaneo et al. (2016) Gibbons and Wu (2020) Pot and Koster (2022)
Assess accessibility as airport/airline performance indicators	Reynolds-Feighan and McLay (2006) Grubestic and Zook (2007) Redondi et al. (2012) Park and O'Kelly (2017) Mueller and Aravazhi (2020) Liao et al. (2022)
Study accessibility as a contributing factor to the tourism industry	Macchiavelli and Vaghi (2003) Sun and Lin (2019)
Explore definition/concept of AAT	Halpern and Bråthen (2011) Banister and Givoni (2013)

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

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 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 travellers’ 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 (Borodako & Rudnicki, 2014; Bowen, 2002; Chou, 1993a, 1993b; Grubestic & Zook, 2007; Macchiavelli & Vaghi, 2003; Mueller, 2021; Toh, 1984). Gravity-based measures can yield results from both infrastructure-based and location-based perspectives even in basic form.

4.4. Theoretical scopes of accessibility (RQ D)

While an ideal study would include all components of accessibility along with their interactions as conceptualised in Figure 1, this is very difficult – if not impossible – due to data limitations and modelling 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.¹ 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 categorised 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.

5. Discussion

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

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 and 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 neighbours) 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 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 and 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 and Lin (2019) explain that a higher proportion of U.K. air travellers preferred destinations located 1000–2000 km away than destinations under 1000 km. This raises the question of what determinants of distance decay would be suitable in gravity-based AAT research.

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 traveller preferences or the attractiveness of locations (Borodako & Rudnicki, 2014; Bowen, 2002; Chou, 1993a, 1993b; Grubestic & Zook, 2007; Mueller, 2021; Mueller & Aravazhi, 2020).

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 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 organisations 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 travellers, 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 travellers, 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 travellers 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 travellers' 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 traveller behaviour. 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 behaviour, 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) travellers. 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 utilised 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 traveller 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.

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 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.

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 travellers, 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 kilometre. 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 behaviour.

6. Avenues for future research (RQ H)

6.1. 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 travellers 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 travellers. 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 utilised 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; Choi et al., 2019; Lee et al., 2016; Molin et al., 2017), as opposed to overall accessibility. Consequently, we only found references to travellers’ 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.

6.2. 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 travellers; 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 travellers 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.

6.3. 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 travellers (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 travellers are assumed to be constant and travellers 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 CO₂ 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).

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.

Note

1. 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.

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