

Evaluating Changes In Airport Spatial Accessibility Using GIS: A Comparative Study Of Adisutjipto And Yogyakarta International Airport (YIA)

Arif Fakhruhin

Sekolah Tinggi Teknologi Kedirgantaraan, Indonesia

Kifni Yudianto

Sekolah Tinggi Teknologi Kedirgantaraan, Indonesia

Maria Valeria Roellyanti

Sekolah Tinggi Teknologi Kedirgantaraan, Indonesia

Corresponding Author: ariffakhrudin21@gmail.com

Abstract

Airport relocation can fundamentally reshape regional accessibility by changing the spatial relationship between transport infrastructure, population Centre's, and economic opportunities. However, evaluating these changes requires more than measuring geographical distance or assessing airport infrastructure in isolation. This study develops a Geographic Information Systems (GIS) based framework to evaluate spatial accessibility differences between Adisutjipto Airport and Yogyakarta International Airport (YIA), Indonesia. Integrating network-based travel time, travel distance, service-area analysis, and opportunity-based accessibility measures, the study compares alternative airport locations across consistent geographical origin zones. Statistical analysis is designed to examine differences in accessibility and the relationships between accessibility outcomes, transportation network characteristics, transport mode availability, and the spatial distribution of population and economic opportunities. The analytical framework distinguishes objective, network-based accessibility from opportunity-based accessibility, providing complementary perspectives on the geographical implications of airport relocation. By applying consistent spatial units and comparable network assumptions, the study offers a systematic approach to identifying areas that may experience relatively favorable or unfavorable airport access conditions. Its principal contribution is a spatially explicit and reproducible framework for evaluating airport accessibility that connects transportation-network

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performance with the geographical distribution of opportunities. The framework also provides a basis for future extensions incorporating historical network data and passenger-level travel behavior to distinguish location-related accessibility differences from broader temporal changes. The proposed approach can support evidence-based airport-access planning, public transport integration, and the prioritization of transport investments in regions experiencing major aviation infrastructure transitions. The findings are intended to inform more spatially responsive and equitable regional transportation planning.

Keywords: Spatial accessibility; Airport relocation; Geographic Information Systems (GIS); Transport network analysis; Airport ground access; Opportunity-based accessibility.

INTRODUCTION

Airports play a strategic role in regional transportation systems by connecting cities, facilitating passenger mobility, and supporting economic interactions across geographical areas. However, the benefits of air transportation depend not only on airport capacity and flight connectivity but also on the accessibility of airports from residential areas, employment Centre's, tourism destinations, and other activity locations. The location of an airport and the performance of the surrounding transport network influence the time, distance, and cost required for passengers to reach airport facilities. Consequently, airport accessibility should be understood as an interaction between transport infrastructure, spatial distribution of activities, and the characteristics of available transportation services rather than simply as the geographical distance between an airport and a city Centre (Geurs & van Wee, 2004; Hansen, 1959).

Accessibility is a fundamental concept in transport geography and transportation planning because it describes the ease with which individuals can reach spatially distributed opportunities through a transportation system. Hansen (1959) established a foundational approach by explaining accessibility in terms of the relationship between transportation impedance and the distribution of opportunities. Subsequent research has demonstrated that accessibility can be measured through different indicators, including travel distance, travel time, cumulative opportunities, and gravity-based measures. These indicators capture different dimensions of accessibility and may produce different evaluations depending on the analytical assumptions and the spatial and temporal characteristics of the data (Geurs & van Wee, 2004; Handy & Niemeier, 1997; Páez et al., 2012). Therefore, a comprehensive assessment of airport accessibility requires



measures that represent both the physical characteristics of transport networks and the relative ease of reaching an airport from different origins.

The development of Geographic Information Systems (GIS) has expanded the possibilities for evaluating accessibility through spatially explicit and network-based approaches. Unlike simple Euclidean distance measurements, network analysis considers the actual configuration of roads, connectivity between links, and travel impedance along available routes. GIS can be used to calculate shortest paths, estimate network travel times, delineate service areas, and identify spatial differences in access across administrative or analytical zones. Furthermore, GIS-based accessibility indicators can be combined with population and economic data to assess how the distribution of opportunities relates to transport network performance. Nevertheless, the choice of accessibility measure remains important because distance-based, time-based, and opportunity-based indicators reflect different dimensions of accessibility and should not automatically be treated as interchangeable (Geurs & van Wee, 2004; Handy & Niemeier, 1997; Páez et al., 2012).

Airport relocation provides a particularly relevant context for examining these relationships because moving an airport changes its spatial position within the regional transportation network. A new airport may offer greater operational capacity and improved aviation infrastructure while simultaneously increasing ground-access distances for some passenger origins. The resulting accessibility changes may be unevenly distributed: locations near the former airport may experience longer journeys to the new facility, whereas locations closer to the new airport may benefit from shorter journeys. These changes also depend on the availability and configuration of road connections, the introduction of public transportation services, and the distribution of population and economic activities. Accordingly, evaluating airport relocation requires more than comparing the geographical distances between two airport locations; it requires an assessment of how the relocation changes the accessibility of different origins through the transport network (Geurs & van Wee, 2004; Páez et al., 2012).

The relocation of airport operations from Adisutjipto International Airport to Yogyakarta International Airport (YIA) in Kulon Progo, Indonesia, provides a relevant empirical setting for this investigation. Adisutjipto Airport was located relatively close to Yogyakarta's urban activity Centre, whereas YIA was developed in the western part of the region to replace the former airport as the principal commercial aviation facility. The change in airport location introduced a different spatial relationship between the airport and major passenger origins, making ground



transportation connectivity an important consideration in the regional transport system. Previous research has investigated the implications of this relocation for the transport network. Fitrada et al. (2019), for example, examined the impact of airport relocation on the regional road network and evaluated infrastructure development scenarios using transport network modelling. Their work demonstrates the importance of evaluating the interaction between airport location, road infrastructure, and transport network performance.

Other studies have examined accessibility and intermodal transportation in the YIA context. Basuki et al. (2019) investigated feeder transport fares and passenger demand for intermodal services associated with the new airport, while Basuki (2023) examined intermodal passenger transport planning and the development of access connections to YIA. In addition, research on public transportation accessibility to YIA has assessed the spatial distribution of airport bus stops and railway stations, including the use of service-area analysis to evaluate the reach of public transport facilities (Sulistyoningrum, 2023). These studies provide useful foundations for understanding airport access, transport integration, and network development in Yogyakarta. However, they address different analytical objectives, ranging from road network performance and transport planning to the accessibility of particular public transportation facilities.

Despite these contributions, further investigation is warranted into the spatial distribution of accessibility changes associated with the relocation itself. In particular, there is an opportunity to establish a consistent GIS-based comparative framework for assessing accessibility to the former and new airport locations across the same set of origin zones. Such a framework would enable researchers to identify which areas experience improvements or declines in accessibility and to quantify the magnitude of those changes using comparable network-based indicators. It would also facilitate the integration of travel time, travel distance, and spatial accessibility measures into a common analytical structure. This approach responds to broader recommendations in accessibility research that measurement choices should be theoretically justified, transparent, and appropriate to the policy question being investigated (Geurs & van Wee, 2004; Handy & Niemeier, 1997; Páez et al., 2012).

The principal research gap addressed in this study is therefore the need for a spatially explicit and systematically comparable assessment of accessibility to the former and new airport locations. Rather than assuming that the relocation necessarily reduced accessibility across the entire region, this study evaluates the geographical distribution and magnitude of accessibility



differences across origin zones. The analysis distinguishes between changes attributable to the airport's spatial relocation and those associated with differences in transport network configuration or service availability, to the extent that the necessary historical and contemporary data can be obtained. This distinction is essential because a simple comparison of the two airport locations using a single contemporary road network measures relative access under that network configuration; it does not, by itself, establish the complete historical effect of relocation. A more robust assessment of change requires comparable network assumptions or reconstructed transport network conditions for the relevant periods.

Based on this research gap, the study aims to evaluate changes in airport spatial accessibility using GIS by comparing Adisutjipto Airport and Yogyakarta International Airport. Specifically, it seeks to: (1) measure network-based travel distance and travel time from selected origin zones to each airport location; (2) identify spatial variations in accessibility using network analysis and service-area mapping; (3) calculate and compare accessibility indicators that incorporate the distribution of population or other relevant opportunities; and (4) identify geographical areas that experience relatively better or poorer accessibility under the alternative airport locations. The analysis will use consistent origin zones and clearly specified network assumptions to ensure that the comparison is analytically meaningful.

The expected contribution of this research is threefold. First, it contributes methodologically by applying a consistent GIS-based framework to compare accessibility to two airport locations within the same regional transportation system. Second, it contributes empirically by providing spatial evidence of the distribution and magnitude of accessibility differences associated with the Adisutjipto–YIA relocation context. Third, it contributes practically by identifying areas where improvements in road connectivity, public transportation coverage, or intermodal integration may be most beneficial. The findings are expected to support evidence-based transportation planning and provide a foundation for more equitable airport access policies in Yogyakarta and other regions experiencing major changes in airport location.

LITERATURE REVIEW AND HYPOTHESES DEVELOPMENT

The Concept of Spatial Accessibility in Airport Transportation

Spatial accessibility is a fundamental concept in transportation planning that describes the ease with which individuals or locations can reach destinations and opportunities through a transportation system. Hansen (1959) conceptualized accessibility as the potential for interaction



between locations, emphasizing the relationship between transportation impedance and the distribution of opportunities. This perspective established the theoretical foundation for subsequent accessibility models that integrate spatial separation, transport costs, and the availability of activities. In airport transportation, spatial accessibility reflects the ease with which passengers from different geographical origins can reach airport facilities through the available transportation network.

Geurs and van Wee (2004) identified four principal dimensions of accessibility assessment: land-use, transportation, temporal, and individual components. The land-use component concerns the distribution of destinations and opportunities, while the transportation component represents the performance of the transport system connecting origins and destinations. The temporal component accounts for the time-dependent availability of transport services and opportunities, whereas the individual component considers differences in users' needs and capabilities. These dimensions indicate that airport accessibility cannot be adequately assessed using geographical distance alone. Instead, a comprehensive assessment should consider network connectivity, travel time, transportation costs, service availability, and the spatial distribution of population and economic activities.

In this study, spatial accessibility is operationalized through GIS-based indicators, including network travel distance, estimated travel time, service-area coverage, and opportunity-based accessibility indices. Travel distance and time provide direct measures of the impedance associated with reaching an airport, while service-area analysis identifies the geographical areas accessible within specified travel thresholds. Opportunity-based measures further indicate the extent to which population or economic activities can reach the airport under a given transportation configuration. Combining these measures provides a multidimensional assessment of airport accessibility and enables the identification of spatial disparities that may not be visible through a single indicator (Handy & Niemeier, 1997; Páez et al., 2012).

Airport Relocation and Spatial Accessibility Changes

Airport relocation represents a major spatial intervention in a regional transportation system because it changes the geographical relationship between the airport, population centers, and supporting transportation infrastructure. Moving an airport away from an established urban Centre may increase the travel distance and time required for some passenger origins, while improving accessibility for locations closer to the new airport. The magnitude and direction of



these changes depend on the existing road network, the development of new transport links, congestion conditions, and the availability of alternative access modes. Therefore, airport relocation should be evaluated as a spatial redistribution of accessibility rather than as a uniform increase or decrease in regional accessibility.

Research on airport relocation has demonstrated the importance of considering the interaction between airport location and transport network performance. Fitrada et al. (2019) investigated the effects of relocating airport operations in the Special Region of Yogyakarta and modelled the implications of road infrastructure development and airport railway services for the regional transport network. Their findings highlight the relevance of supporting transport infrastructure in accommodating travel demand associated with the new airport. However, road network performance and spatial accessibility are related but distinct analytical outcomes: the former concerns network operation and congestion, whereas the latter concerns the ease of reaching a destination from different origins.

For the Adisutjipto YIA case, comparing accessibility to the two airport locations provides an opportunity to examine how the relocation changes the spatial distribution of access across the Yogyakarta region. The comparison should use consistent origin zones and clearly specified network assumptions to ensure that differences are attributable to the alternative airport locations rather than inconsistent measurement procedures. Where historical road-network data are available, the analysis can compare reconstructed pre-relocation conditions with the subsequent transport system. Where such data are unavailable, a common contemporary network can be used to isolate the spatial effect of airport location, although the results should then be interpreted as a location-based comparison rather than a complete estimate of historical change. Accordingly, the first hypothesis is formulated as follows:

H1: Spatial accessibility differs significantly between the Adisutjipto Airport location and the Yogyakarta International Airport (YIA) location across the selected origin zones.

This hypothesis concerns the existence and distribution of accessibility differences. It does not presume that all zones experience reduced accessibility after relocation; the direction and magnitude of the differences must be established empirically.

Transportation Network Characteristics and Airport Accessibility

Transportation network characteristics determine the physical connectivity between origins and destinations and influence the impedance associated with travel. Relevant



characteristics include network length, road hierarchy, link connectivity, travel speed, congestion, and the availability of alternative routes. A well-connected network can provide more direct routes and reduce travel impedance, whereas discontinuities, limited road capacity, and congestion can increase travel time even when geographical distances are relatively short. Consequently, network characteristics are essential determinants of network-based airport accessibility (Geurs & van Wee, 2004; Handy & Niemeier, 1997).

GIS network analysis enables these characteristics to be incorporated into accessibility measurement by calculating routes and travel impedance along connected transport links rather than through straight-line distances. Origin–destination cost matrices and shortest-path algorithms can estimate travel distance and time, while service-area analysis can identify the areas reachable within specified thresholds. The resulting measures provide an empirical basis for assessing whether network configuration facilitates or constrains access to the two airport locations. A related study by Sulistyoningrum (2023) applied GIS network analysis to evaluate public transportation access to YIA, demonstrating the relevance of network-based distance, travel time, and service-area measures in the local context. Based on this theoretical and methodological foundation, the following hypothesis is proposed:

H2: Transportation network characteristics are significantly associated with network-based accessibility to the airport locations.

The expected direction depends on the specific network indicator. Higher effective travel speeds and stronger connectivity are expected to improve accessibility, whereas longer travel distances and greater travel-time impedance are expected to reduce it. These indicators should therefore be coded and interpreted according to their individual meanings rather than combined indiscriminately into a single network score.

Availability of Transportation Modes and Airport Accessibility

The availability of transportation modes is another important dimension of airport accessibility. Passengers may reach an airport using private vehicles, taxis, buses, airport railway services, or combinations of different modes. Each mode differs in travel time, frequency, monetary cost, service coverage, and transfer requirements. Consequently, two locations with similar road-network distances may have substantially different practical accessibility if one has more reliable public transportation connections or more convenient intermodal services.



The relationship between transportation modes and airport accessibility is particularly relevant when an airport is relocated away from an established urban Centre. New access services may reduce the disadvantages associated with greater geographical distance, whereas limited service frequency, inconvenient departure schedules, or difficult transfers may increase the overall burden of reaching the airport. Research on airport ground-access mode choice has also demonstrated that passengers' decisions are influenced by the characteristics of available modes and the conditions under which they access the airport (Jou et al., 2011). In the YIA context, the availability of airport railway and bus services provides an important dimension for evaluating the relationship between transport integration and airport access.

Nevertheless, the availability of transportation modes should be distinguished from the objective accessibility index calculated using a road-only GIS network. Road-network analysis alone cannot fully represent the benefits of railway or scheduled bus services. To incorporate these services adequately, the research should construct a multimodal network or calculate mode-specific accessibility indicators that account for service frequency, waiting time, transfer penalties, and access to stations or stops. This distinction is necessary to prevent the overestimation or underestimation of accessibility benefits associated with public transportation. The corresponding hypothesis is:

H3: The availability and integration of transportation modes are significantly associated with airport accessibility.

A positive relationship is expected when greater service availability and better modal integration reduce the total impedance of reaching the airport. However, this relationship should be evaluated using actual service characteristics rather than the number of transportation modes alone.

Origin Zone Characteristics and Opportunity Based Accessibility

Accessibility is influenced not only by the transport network but also by the spatial distribution of population and economic opportunities. Hansen's (1959) framework emphasizes that accessibility depends on both the impedance of reaching destinations and the opportunities available at those destinations. In airport accessibility research, the spatial distribution of population, employment, tourism activities, and other relevant origins or opportunities can help explain why the same airport location may be relatively accessible to some areas but less accessible to others.



For the present study, origin-zone characteristics may include population density, employment concentration, tourism activity, and other spatially relevant indicators supported by available data. These variables should be incorporated into the accessibility calculation according to their theoretical role. Population or employment may represent opportunities, whereas population density may represent the concentration of potential users at an origin. They should not automatically be treated as equivalent indicators. This distinction will improve the interpretability of the resulting accessibility measures and support the identification of geographical areas where transport improvements may benefit larger populations. The fourth hypothesis is therefore formulated as follows:

H4: The distribution of population and economic opportunities is significantly associated with opportunity-based airport accessibility across origin zones.

This hypothesis concerns differences in opportunity-based accessibility. Its empirical interpretation depends on the specification of the gravity model, the selection of opportunity indicators, and the calibration or justification of the impedance-decay parameter.

Generalized Travel Cost as a Mediating Mechanism

Generalized travel cost represents the overall burden of a journey by incorporating both monetary expenses and the value of time. It provides a broader measure of travel impedance than distance or travel time alone because passengers may experience different costs even when travelling similar distances. Relevant components may include fares, fuel expenditure, parking charges, tolls, access-mode costs, waiting time, and transfer time. The relative importance of these components depends on the transport modes available and the characteristics of individual travelers.

Generalized cost offers a useful way to explain why airport accessibility may differ even when travel distances are comparable. For example, an airport railway service may involve a longer geographical journey but offer predictable travel times and competitive monetary costs. Conversely, a shorter road journey may be less attractive under congested conditions or when parking expenses are high. Thus, generalized cost can be used to compare the overall impedance associated with alternative airport-access arrangements.

For this study, generalized cost is most appropriately treated as an explanatory mechanism in a user-level model of experienced accessibility or airport-access mode choice. It should not automatically be inserted as a mediator between network characteristics and an



objective GIS accessibility index when travel time and monetary costs are already components of that index. Such a specification would risk mathematical overlap between the mediator and the dependent variable. The following hypothesis is proposed for the user-level explanatory component:

H5: Generalized travel cost mediates the relationship between airport-access transportation characteristics and users' perceived accessibility.

The hypothesized indirect effect is that transportation characteristics influence the overall cost of reaching the airport, which in turn influences how accessible the airport is perceived to be. This hypothesis requires individual-level survey data and a distinct measure of perceived accessibility.

Socioeconomic Characteristics as Moderating Factors

The consequences of airport relocation may differ among travelers because individuals have different financial resources, travel purposes, and access to private transportation. Income may influence the affordability of airport-access services, while vehicle ownership may affect the availability of alternatives to public transportation. Trip purpose may also influence the importance attached to travel time, reliability, convenience, and total monetary expenditure.

These differences suggest that the relationship between generalized travel cost and perceived accessibility may not be uniform across all users. For example, travelers with limited financial resources may be more sensitive to increases in fares or other monetary expenses, whereas travelers with substantial time constraints may place greater importance on travel-time reliability. Vehicle ownership may alter the alternatives available to a traveler, while the requirements of business and leisure journeys may produce different assessments of acceptable access conditions.

The individual component of accessibility identified by Geurs and van Wee (2004) provides a theoretical basis for examining these differences. However, income, trip purpose, and vehicle ownership should be measured separately because they represent distinct socioeconomic and behavioral characteristics rather than a single homogeneous construct. Accordingly, the sixth hypothesis is formulated as follows:

H6: Users' socioeconomic characteristics, including income, trip purpose, and vehicle ownership, moderate the relationship between generalized travel cost and perceived airport accessibility.



The direction of moderation should be specified for each characteristic based on the theoretical argument and operational measurement. For example, income may influence sensitivity to monetary cost, while trip purpose may influence sensitivity to travel time. These effects should be tested through appropriate interaction terms or multigroup analysis rather than inferred from differences in descriptive statistics alone.

Research Framework and Hypotheses Summary

The literature review establishes two related analytical components. The first is an objective, spatial component that compares accessibility to Adisutjipto Airport and YIA through GIS-based network analysis. The second is an explanatory, user-level component that investigates whether generalized cost and socioeconomic characteristics help explain differences in perceived accessibility. Maintaining this distinction is important because spatial indicators derived from GIS and individual perceptions measured through questionnaires represent different units of analysis.

The proposed hypotheses are summarized below.

Hypothesis	Proposed relationship	Analytical approach
H1	Accessibility differs between the Adisutjipto and YIA locations	Paired comparison across origin zones
H2	Transportation network characteristics are associated with airport accessibility	GIS indicators and regression analysis
H3	Transportation-mode availability and integration are associated with airport accessibility	Multimodal accessibility analysis and regression
H4	Population and economic opportunities are associated with opportunity-based accessibility	Hansen/gravity-based accessibility analysis
H5	Generalized cost mediates the relationship between transport characteristics and perceived accessibility	Mediation analysis using survey data
H6	Socioeconomic characteristics moderate the relationship between generalized cost and perceived accessibility	Interaction analysis or multigroup analysis

H1–H4 form the core spatial-accessibility investigation. H5–H6 constitute an additional user-level explanatory component and require survey data that are distinct from the GIS-derived



indicators. If the study is limited to secondary spatial data, H5 and H6 should be omitted rather than tested using aggregate GIS indicators.

The resulting framework contributes to airport accessibility research by combining network-based spatial comparison with a theoretically grounded explanation of user-level accessibility differences. It also provides a practical basis for identifying geographical areas that may require improved road connectivity, public transportation coverage, or intermodal integration following airport relocation.

RESEARCH METHODOLOGY

Research Design

This study adopts a quantitative research design to evaluate changes in spatial accessibility associated with the relocation of Adisutjipto Airport to Yogyakarta International Airport (YIA). The research integrates Geographic Information Systems (GIS)-based spatial network analysis with comparative statistical analysis to examine how airport location, transportation network characteristics, transport mode availability, and the spatial distribution of population and economic opportunities relate to airport accessibility. This approach enables accessibility to be assessed not only in terms of physical distance but also through network-based travel time, travel distance, and the potential for people to reach relevant transportation facilities and opportunities.

The methodological framework consists of two complementary analytical components. The first component focuses on objective, spatially derived accessibility measures using GIS and addresses Hypotheses H1–H4. The second component, if supported by primary survey data, examines users' perceived accessibility and the potential mediating role of generalized travel cost, as well as the moderating effects of socioeconomic characteristics, corresponding to Hypotheses H5–H6. Separating these components ensures that spatial indicators measured at the origin-zone level are not conflated with individual perceptions measured at the respondent level. The integration of these analytical components provides a broader understanding of airport accessibility while maintaining consistency between the research questions, measurement procedures, and statistical techniques.



Study Area and Unit of Analysis

The study focuses on the Special Region of Yogyakarta, Indonesia, with particular attention to the geographical relationship between the former Adisutjipto Airport and YIA in Kulon Progo Regency. These two airport locations provide the basis for examining how the geographical relocation of airport infrastructure may redistribute accessibility across different parts of the region. Adisutjipto Airport represents the former airport location, whereas YIA represents the new location serving Yogyakarta and its surrounding areas.

For the GIS analysis, the primary unit of analysis is the geographical origin zone. Origin zones will be established using an appropriate administrative or spatial aggregation, such as subdistricts, villages, or population-weighted grid cells, depending on data availability and spatial resolution. Each origin zone will be connected to both airport locations through the road network and, where sufficiently detailed data are available, through public transportation networks. Using the same origin zones for both airport locations provides a consistent spatial basis for comparison and reduces the risk that differences in results arise from changes in the geographical units rather than from differences in airport location.

For the individual-level analysis, the unit of analysis is the airport user. This component is relevant only if primary survey data are collected to measure perceived accessibility, travel costs, and respondents' socioeconomic characteristics. The spatial and individual-level datasets will be linked through common geographical identifiers where appropriate, without treating individual responses as independent spatial observations or assuming that zone-level relationships automatically apply to individuals.

Data Collection and Sources

The study will use secondary spatial and transportation data as the principal inputs for GIS-based accessibility analysis. These data will include road-network geometry, road classification, network connectivity, travel speeds or travel-time attributes, airport locations, administrative boundaries, population distribution, land use, and the geographical distribution of relevant economic activities or public facilities. Additional information concerning public transportation routes, service frequency, operating schedules, transfer points, and intermodal connections will be incorporated when reliable and sufficiently detailed data are available.

Potential data sources include official statistical publications from Statistics Indonesia (Badan Pusat Statistik), regional planning documents, government transportation agencies,



airport related publications, and other authoritative geospatial datasets. OpenStreetMap and other openly accessible spatial databases may be used to supplement the road-network data, subject to verification and quality assessment. Data from different sources will be harmonized to ensure consistency in coordinate reference systems, geographical coverage, spatial resolution, and observation periods.

The study will distinguish between two possible comparative approaches. First, a common-network location comparison will evaluate accessibility to the former and new airport locations using the same origin zones and a consistent road network. This approach primarily identifies the spatial implications of airport location under a common network configuration. Second, a historical before and after comparison may be undertaken if comparable historical road-network, public transportation, and service data can be obtained. The latter approach is necessary to investigate changes associated with the relocation alongside contemporaneous developments in transportation infrastructure. The distinction is important because differences between the two airport locations do not, by themselves, establish that every observed change was caused exclusively by the relocation.

If Hypotheses H5 and H6 are retained, primary data will additionally be collected through a structured questionnaire administered to airport users. The questionnaire will capture travel origin, trip purpose, household income category, vehicle ownership, access mode, perceived accessibility, travel time, monetary expenditure, and relevant travel experiences. Survey questions will be developed from established concepts in the transportation accessibility and travel-behavior literature and adapted to the Yogyakarta context. A pilot test will be conducted to assess question clarity and response consistency before the main survey is administered. Secondary GIS data and survey responses will be documented separately to preserve the distinction between objective spatial conditions and subjective user experiences.

Measurement of Spatial Accessibility

Spatial accessibility will be operationalized through complementary network-based and opportunity-based indicators. The first set of indicators comprises network travel time and travel distance between each origin zone and the two airport locations. Network travel distance will be calculated along feasible road routes rather than using straight-line geographical distance. Network travel time will be estimated from road-segment lengths and representative travel speeds or from validated travel-time data, depending on availability. Where possible, different



travel conditions will be considered to avoid interpreting free-flow estimates as universally representative of actual journeys.

The second set of indicators concerns service areas and isochrones. GIS network analysis will identify the geographical areas reachable from each airport location within specified travel-time thresholds. The thresholds will be selected based on the characteristics of the study area, available travel data, and the policy relevance of the analysis. Comparing the resulting service areas will reveal whether the new airport location expands or reduces the geographical coverage of airport access for different origin zones.

The third set of indicators captures opportunity-based accessibility. Following Hansen's (1959) conceptualization of accessibility and subsequent developments in accessibility measurement, a gravity-based indicator will be calculated to assess the potential for residents to reach relevant destinations or opportunities. Because this study examines access to airport infrastructure, the analysis will also distinguish between accessibility to the airport and accessibility to opportunities served by the wider transport system. Travel time and distance to the airport will be the principal airport-access indicators, while the gravity-based measure will provide a complementary assessment of the relationship between travel impedance and the distribution of relevant opportunities. The indicators will be interpreted according to their specific meanings rather than treated as interchangeable measures.

Transportation Network Characteristics and Transport Mode Availability

Transportation network characteristics will be examined to determine their association with airport accessibility. Relevant indicators include network distance, road connectivity, road hierarchy, the availability of alternative routes, and travel-time conditions. Where data permit, network connectivity may be measured using indicators such as intersection density, link-node relationships, or network density. These variables will be derived consistently across the selected origin zones to facilitate comparison.

Transport mode availability and integration will be assessed using information about the availability of private vehicles, buses, airport shuttle services, airport rail services, and other relevant public transportation connections. Indicators may include the presence of a service, route coverage, service frequency, waiting time, transfer requirements, and the ease of connecting between modes. The specific indicators will depend on the completeness and comparability of the available data.



The analysis will distinguish between the physical availability of transportation infrastructure and the operational availability of transport services. The existence of a road or railway does not necessarily mean that users can access a reliable service at a reasonable time or cost. Accordingly, mode availability and intermodal integration will be assessed using operational data wherever possible. These indicators will be used to examine whether differences in network conditions and transport services are associated with differences in accessibility across origin zones.

Generalized Travel Cost and Socioeconomic Characteristics

For the individual-level survey component, generalized travel cost will be used to represent the combined burden of monetary expenditure and travel time.

The use of generalized travel cost is intended to capture the broader burden experienced by airport users, rather than merely the geographical distance between an origin and the airport. Nevertheless, generalized cost will be treated as a distinct construct from perceived accessibility. Its role as a mediator will be evaluated only when the proposed model establishes a theoretically defensible relationship between transportation characteristics, generalized cost, and perceived accessibility.

Socioeconomic characteristics will include household income category, trip purpose, and vehicle ownership. These variables will be examined as potential moderators of the relationship between generalized travel cost and perceived accessibility. For example, the implications of a given access cost may differ between users with different income levels, between business and leisure travelers', or between users who have access to private vehicles and those who depend on public transportation. These relationships will be assessed using individual-level survey data rather than inferred from aggregate GIS indicators.

GIS Processing and Analytical Procedures

GIS processing will be conducted using QGIS, ArcGIS, or an equivalent geographic information system capable of network analysis. The first stage will involve data preparation, including checking spatial completeness, correcting geometry errors where necessary, harmonizing coordinate reference systems, and verifying the connectivity and attributes of the transportation network. Road segments will be assigned suitable impedance values, such as travel time or distance, based on available information.



The second stage will involve constructing origin-to-destination connections from each selected origin zone to both airport locations. A network-based origin–destination cost matrix will be generated to obtain comparable travel-time and travel-distance estimates. Service-area or isochrone analysis will then be performed to identify the geographical coverage of each airport location under selected travel-time thresholds. Where data are sufficient, alternative network configurations or transport-mode scenarios will be examined to assess the sensitivity of accessibility outcomes to transportation conditions.

The third stage will calculate opportunity-based accessibility indicators using the selected destination opportunities and impedance function. Population and economic-opportunity data will be spatially joined or aggregated to appropriate geographical units. All indicators will be calculated using consistent assumptions across the two airport locations. Maps, descriptive statistics, and spatial summaries will be produced to identify geographical patterns, including areas that experience relatively improved or reduced access under the alternative airport-location scenarios.

Finally, the derived indicators will be exported for statistical analysis. Data quality checks will be conducted to identify missing values, implausible travel times, disconnected network segments, and other potential sources of error. Sensitivity analysis will be considered for assumptions concerning travel speeds, impedance functions, service-area thresholds, and spatial aggregation. These procedures are intended to improve the transparency, reproducibility, and robustness of the accessibility assessment.

Statistical Analysis and Hypothesis Testing

The statistical analysis will be aligned with the six hypotheses and the level at which each construct is measured. H1 will be examined by comparing network-based accessibility indicators for Adisutjipto and YIA across the same origin zones. For continuous paired measures, such as travel time and network distance, a paired-samples (t)-test will be used when the distribution of paired differences reasonably satisfies the relevant assumptions. If these assumptions are not met, the Wilcoxon signed-rank test will be considered. Results will include descriptive statistics, estimated differences, confidence intervals, and appropriate effect-size measures. If the analysis covers several accessibility indicators or multiple travel-time thresholds, the testing strategy will account for the risk of multiple comparisons.



H2 will be evaluated by examining the association between transportation network characteristics and network-based accessibility. Depending on the distribution and structure of the data, multiple regression or an appropriate spatial statistical model may be applied. Potential explanatory variables include road connectivity, network density, road hierarchy, and travel-time conditions. Model specification will consider multicollinearity, residual behavior, and the possibility of spatial dependence. If spatial dependence is material, an appropriate spatial regression specification will be considered rather than relying solely on conventional regression.

H3 will assess the association between transport mode availability or integration and airport accessibility. The analysis may use regression models or structured comparisons across origin zones, depending on how modal availability is measured. Where multiple transport modes are included, the model will distinguish service presence from service quality or frequency whenever the available data permit. H4 will examine the relationship between population and economic-opportunity distributions and opportunity-based accessibility using the selected gravity-based indicator. The model will consider the potential influence of spatial concentration and differences in the geographical distribution of opportunities. Interpretation will focus on statistical associations unless the research design and data support stronger causal conclusions.

H5 and H6 will be examined only if an adequate individual-level survey dataset is available. H5 will assess whether generalized travel cost mediates the relationship between relevant transportation characteristics and perceived accessibility. The indirect effect will be estimated using a suitable mediation procedure, preferably with bootstrap confidence intervals. H6 will examine whether socioeconomic characteristics moderate the relationship between generalized travel cost and perceived accessibility. Interaction terms will be specified for the relevant moderator variables, and their conditional effects will be interpreted at meaningful values or categories of the moderators.

If the survey model uses multiple-item latent constructs, the measurement model will be assessed before interpreting structural relationships. Reliability and validity checks will be selected according to the measurement approach, and the choice between regression-based mediation/moderation and structural equation modelling will depend on the nature of the constructs, sample size, and model complexity. If perceived accessibility is measured using a single observed item or a composite score, an appropriate regression-based approach may be more suitable than structural equation modelling.



Importantly, the GIS and survey components will not be combined into a single statistical model without a defensible linkage between their units of analysis. In addition, generalized travel cost will not be used as a mediator of an objective accessibility indicator when the indicator itself is directly calculated from the same travel-time and monetary-cost components. Such overlap could create a mechanical relationship rather than demonstrate a meaningful mediation mechanism.

Reliability, Validity, and Ethical Considerations

The reliability of the spatial analysis will be supported through consistent network definitions, documented data sources, transparent impedance assumptions, and comparable calculations across the two airport locations. Where feasible, the results will be checked against alternative travel-speed assumptions, different spatial aggregation levels, and alternative specifications of the opportunity-based accessibility function. The study will also document limitations associated with missing service data, incomplete historical records, and variations in network conditions.

For the survey component, questionnaire clarity will be assessed through pilot testing, while measurement reliability and validity will be examined using methods appropriate to the selected constructs and statistical model. Survey participation will be voluntary, and respondents will be informed about the purpose of the research and how their information will be used. Personal identifiers will not be reported in the analysis, and individual responses will be handled confidentially. Any necessary institutional ethics approval or research permissions will be obtained before data collection.

Methodological Limitations

Several limitations will be considered when interpreting the findings. First, estimated network travel times may not fully capture actual travel conditions if reliable time-dependent traffic data are unavailable. Second, the availability of public transportation information may vary across modes and observation periods, affecting the precision of intermodal accessibility estimates. Third, the comparison of the two airport locations using a common contemporary network identifies differences attributable to the location scenarios under shared network assumptions but does not, by itself, establish the complete historical effect of airport relocation.



A stronger before-and-after interpretation requires comparable historical transportation-network and service data.

Furthermore, opportunity-based accessibility measures depend on the selection of destinations, the spatial resolution of the data, and the specification of the impedance function. The optional survey component may also be subject to sampling limitations and self-reported measurement error. These limitations will be acknowledged when discussing the findings and formulating recommendations for regional transportation planning. Despite these constraints, the combination of consistent GIS network analysis, opportunity-based accessibility measurement, and appropriately specified statistical tests provides a systematic framework for evaluating the spatial implications of the airport relocation.

RESULTS AND DISCUSSION

Descriptive Results of Airport Spatial Accessibility

The GIS-based analysis was designed to compare spatial accessibility to Adisutjipto Airport and Yogyakarta International Airport (YIA) across a common set of geographical origin zones. The comparison focused on network travel time, network travel distance, service-area coverage, and opportunity-based accessibility. These indicators were used to identify how the geographical relocation of airport infrastructure may redistribute accessibility across the study area.

The analysis covered 30 origin zones distributed across the Special Region of Yogyakarta. The hypothetical descriptive results indicate that accessibility differs between the two airport locations, with the direction and magnitude of the difference varying across geographical areas. Origin zones situated near the urban core of Yogyakarta generally exhibit shorter access times to Adisutjipto Airport, whereas some zones located closer to Kulon Progo and the western corridor may experience relatively more favorable access to YIA.

Table 1. Descriptive statistics of airport accessibility

Accessibility indicator	Adisutjipto Airport	YIA
Mean network travel time (minutes)	38.6	62.4
Mean network travel distance (km)	25.7	43.8
Origin zones reachable within 60 minutes	83%	57%



Relative geographical advantage	Urban and eastern areas	Western areas closer to YIA
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The pattern suggests that airport relocation may redistribute access rather than uniformly improve or reduce accessibility throughout the region. The new airport location may offer geographical advantages for residents and activities located near the western corridor, while users originating from more distant urban or eastern areas may face longer journeys. This finding highlights the importance of evaluating airport accessibility from the perspective of the entire regional transport system rather than relying solely on the location or operational capacity of the airport.

The descriptive results also demonstrate why straight-line distance alone is insufficient for evaluating accessibility. Actual access depends on the configuration of the road network, available routes, travel speeds, congestion, and the availability of public transportation. Consequently, two origin zones with similar geographical distances from an airport may experience different travel burdens because of differences in network connectivity and transportation services.

Comparative Analysis of Accessibility Between Adisutjipto Airport and YIA

Hypothesis H1 proposed that spatial accessibility differs significantly between the former and new airport locations across selected origin zones. This hypothesis was evaluated by comparing network-based travel time and distance for the same origin zones under both airport-location scenarios.

In the mean network travel time to YIA was 62.4 minutes, compared with 38.6 minutes to Adisutjipto Airport. The mean difference was therefore 23.8 minutes. The hypothetical paired-samples test produced a statistically significant difference, with a 95% confidence interval of 19.2–28.4 minutes and a p-value below .001. A corresponding comparison of network travel distance also indicated a difference between the two locations.

Table 2. Comparison of network accessibility

Indicator	Mean difference (YIA – Adisutjipto)	Illustrative statistical result
Network travel time	+23.8 minutes	95% CI [19.2, 28.4]; p < .001



Network travel distance	+18.1 km	p < .001
Overall interpretation	Longer average access under the YIA scenario	H1 supported in this hypothetical example

The comparison indicates that the change in airport location may have increased average access time and distance for the selected origin zones. However, this average difference does not imply that all origin zones experienced a deterioration in accessibility. The spatial distribution of the differences is important because accessibility changes may be positive for locations closer to YIA and negative for locations that were previously well connected to Adisutjipto Airport.

This interpretation is consistent with the understanding of accessibility as a spatially differentiated outcome of interactions between geographical location and transport networks (Geurs & van Wee, 2004; Handy & Niemeier, 1997). From this perspective, airport relocation can alter the relative advantage of different locations even when the total capacity of the airport system increases. A more distant airport may serve the region effectively while simultaneously imposing additional access burdens on certain population groups or geographical areas.

Nevertheless, the comparison must be interpreted according to its research design. If both airport locations are evaluated using a common contemporary road network, the result reflects differences between alternative airport-location scenarios under that network configuration. It does not independently establish the complete historical effect of relocation, because actual changes may also reflect road construction, transport-service development, congestion, and changes in travel behavior.

Spatial Distribution of Airport Accessibility

The service-area analysis provides a geographical interpretation of the differences observed in the network travel-time results. In the illustrative scenario, the service areas indicate that Adisutjipto Airport offers relatively favorable access for origin zones concentrated around the urban core and eastern parts of the study area. By contrast, YIA offers a relative geographical advantage for origin zones situated closer to the western part of the region.

The resulting pattern illustrates a spatial redistribution of airport accessibility. Rather than producing a single region-wide outcome, relocation changes the relative travel burden across origin zones. Areas located closer to the new airport may benefit from shorter access routes,



while areas farther away may become more dependent on road connectivity, public transportation availability, and intermodal integration.

The service area results should also be interpreted alongside the characteristics of the transportation network. An origin zone located relatively close to an airport may still have poor practical accessibility if the available road network is indirect or public transportation connections are limited. Conversely, a geographically distant zone may retain reasonable access when direct routes, reliable public transport, and efficient transfers are available.

This finding reinforces the distinction between geographical proximity and functional accessibility. Hansen's (1959) accessibility framework emphasizes the relationship between locations and the opportunities that can be reached from them. In the airport context, this means that the geographical position of an airport cannot be evaluated independently of the transport connections that enable passengers to reach it.

Transportation Network Characteristics and Airport Accessibility

Hypothesis H2 proposed that transportation network characteristics are significantly associated with network-based airport accessibility. To examine this relationship, the proposed analysis considers road connectivity, network density, route characteristics, and travel-time conditions as potential explanatory factors.

For illustration, suppose that a regression model was estimated using origin-zone accessibility as the dependent variable and standardized transportation-network indicators as explanatory variables. The hypothetical results indicate that higher road connectivity and greater network density are associated with shorter access times, whereas higher congestion levels are associated with longer travel times. The standardized coefficients are presented in Table 3.

Table 3. Associations between network characteristics and access travel time

Explanatory variable	Standardized coefficient (β)	Illustrative interpretation
Road connectivity	-0.31	Higher connectivity is associated with shorter access time
Road-network density	-0.27	Greater network density is associated with shorter access time



Congestion level	+0.34	Higher congestion is associated with longer access time
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The findings suggest that airport accessibility depends not only on airport location but also on the structure and operating conditions of the surrounding transportation network. Better-connected road networks may provide more direct routes and additional route alternatives, reducing travel impedance. Conversely, congestion may reduce the effective accessibility of an airport even when its geographical distance from an origin zone is relatively short.

These relationships are consistent with the broader accessibility literature, which conceptualizes access as an interaction between the distribution of destinations and the cost of reaching them (Geurs & van Wee, 2004). In this context, network connectivity represents an important component of the spatial relationship between airport infrastructure and its potential users.

However, the magnitude and direction of these associations must be established empirically. The final analysis should report coefficient estimates, standard errors, confidence intervals, p-values, model fit, and diagnostic results. Where the spatial arrangement of origin zones produces substantial spatial dependence, a spatial regression model may be more appropriate than a conventional regression model.

Transport Mode Availability and Airport Accessibility

Hypothesis H3 proposed that the availability and integration of transport modes are significantly associated with airport accessibility. The analysis considers whether origin zones with better access to public transportation services and more effective intermodal connections experience more favorable airport access conditions.

In the illustrative scenario, origin zones served by more direct public transportation connections exhibit lower estimated access burdens than zones that require multiple transfers or rely predominantly on indirect road connections. The hypothetical analysis suggests that transport availability alone may not fully explain accessibility differences. Service frequency, waiting time, transfer requirements, and the alignment between connecting services may also influence the overall travel burden.

This distinction is important because the presence of a transport mode does not automatically ensure effective accessibility. A railway station, bus stop, or airport shuttle service



may exist within a region but remain difficult to use if the service is infrequent, poorly connected to residential areas, or incompatible with passengers' travel schedules.

The findings therefore suggest that transport integration should be considered alongside physical infrastructure. A coordinated combination of road access, feeder services, public transport, and reliable intermodal transfers may improve access to an airport more effectively than infrastructure expansion considered in isolation.

This interpretation is particularly relevant to YIA because airport access involves the relationship between the airport's geographical position and the wider regional transport system. Previous research on airport relocation and transportation networks in Yogyakarta has also highlighted the relevance of network conditions and transport infrastructure scenarios when evaluating the implications of a new airport location (Fitrada et al., 2019). Nevertheless, the final study must establish the relationship between specific service indicators and accessibility using verified transportation data rather than assuming that all modes contribute equally.

Population Distribution, Economic Opportunities, and Opportunity-Based Accessibility

Hypothesis H4 proposed that the distribution of population and economic opportunities is significantly associated with opportunity-based accessibility across origin zones. This hypothesis extends the analysis beyond travel time and distance by considering how transportation impedance interacts with the spatial distribution of relevant opportunities.

The results suggest that opportunity-based accessibility may differ from the pattern identified through average travel time alone. Origin zones with relatively high population density or concentrated economic activity may retain substantial accessibility advantages because of their proximity to multiple destinations and established transportation connections. Other zones may experience improved relative access to YIA because of their geographical position, even when their population density is comparatively lower.

The distinction reflects the conceptual difference between reaching an airport and reaching opportunities through a transportation system. Network travel time to the airport measures the burden of reaching a specific destination. A gravity-based accessibility indicator, in contrast, evaluates the relationship between travel impedance and the distribution of selected opportunities across destinations. The two measures provide complementary but non-equivalent information.



Hansen's (1959) framework provides a theoretical basis for this opportunity-based perspective by defining accessibility in relation to the potential for interaction between locations. Geurs and van Wee (2004) further emphasize that accessibility measurement depends on the interaction between land use, transport, and the characteristics of the population being considered.

For the present study, this implies that the consequences of airport relocation should not be assessed exclusively through average travel time. The spatial distribution of population and economic activities may influence the number of people affected by longer or shorter journeys and the geographical concentration of potential benefits. The final analysis should therefore examine whether the results remain consistent across alternative opportunity measures and impedance specifications.

Because population density and economic activity may be spatially concentrated, the statistical analysis should also consider possible spatial dependence and differences in the scale of geographical aggregation. A positive association between opportunity concentration and an accessibility index should not automatically be interpreted as evidence that population concentration causes better airport access; the relationship may also reflect historical urban development and the location of transportation infrastructure.

Discussion of the Main Findings

Taken together, the illustrative results demonstrate how GIS-based network analysis can be used to evaluate the spatial implications of airport relocation. The central analytical insight is that relocation may redistribute accessibility across geographical areas rather than create a uniform improvement or deterioration. The direction and magnitude of the effect depend on the relationship between airport location, transportation-network configuration, transport-service availability, and the spatial distribution of population and economic activities.

First, the comparative analysis highlights the importance of evaluating airport accessibility across consistent origin zones. Without a common spatial basis, differences in the geographical units selected for analysis may influence the observed results. By comparing access to both airport locations from the same origins, the study can more clearly identify how alternative airport locations alter travel impedance under the specified network conditions.

Second, the network analysis emphasizes that airport location and transportation infrastructure should be considered jointly. A new airport may be strategically positioned for



regional development, but its accessibility depends on the quality of the connecting network and the availability of effective transport services. Improvements in road connectivity, public transportation, and intermodal integration may reduce access burdens for some zones, although the benefits may not be distributed equally across the region.

Third, the opportunity-based analysis broadens the interpretation of accessibility by considering population and economic activity. A change in average travel time does not necessarily correspond to an equivalent change in the number of people affected or the opportunities they can reach. Therefore, network-based travel indicators and opportunity-based measures should be interpreted together when assessing the regional implications of airport relocation.

These findings are conceptually consistent with the view that accessibility is a multidimensional property of the transport and land-use system rather than a simple measure of geographical distance. They also highlight the need to distinguish between the spatial consequences of an airport's location and the broader historical effects of its relocation. The latter may include changes in road infrastructure, public transport provision, settlement patterns, and economic activity, which require additional temporal data to identify reliably.

Implications for Transportation Planning and Regional Development

The findings have several potential implications for regional transportation planning. First, airport-access planning should identify origin zones that experience relatively high access burdens and assess whether these patterns correspond to gaps in road connectivity, public transport coverage, or intermodal integration. Targeted interventions may be more effective than uniform infrastructure investment across the entire region.

Second, improvements in public transportation should consider the complete passenger journey, including access to stations or stops, waiting time, transfer requirements, and service coordination. The practical value of an airport rail or shuttle service depends partly on how easily passengers can reach it from their origins and how reliably it connects with other modes. Consequently, planning should evaluate the entire access chain rather than individual transport facilities in isolation.

Third, regional authorities should incorporate spatial accessibility indicators into land-use and transport planning. Service-area maps and origin-zone accessibility measures can help identify areas where transport investment may be needed and provide a transparent basis for



comparing alternative network scenarios. Where population and economic-opportunity data are available, these indicators can also help distinguish improvements in geographical coverage from improvements that benefit larger numbers of residents or economic activities.

Finally, accessibility outcomes should be evaluated alongside broader regional objectives. Shorter travel time is an important indicator, but it does not fully capture affordability, reliability, service availability, or differences in users' capacity to access transportation. Future evaluations may therefore combine objective GIS indicators with user-level survey data to examine how access burdens are experienced by different population groups.

Limitations and Directions for Further Research

The interpretation of the results should account for several methodological limitations. Network travel-time estimates depend on the accuracy of road-network data, assumed travel speeds, and the availability of traffic information. Where observed, time-dependent travel data are unavailable, estimated travel times may not represent conditions during peak periods or periods of unusually high demand.

The analysis may also be constrained by incomplete public transportation information. Route coverage alone does not capture service frequency, operating hours, waiting time, or the reliability of connections. Similarly, opportunity-based accessibility depends on the selection of destinations, the spatial resolution of the data, and the specification of the distance-decay function.

A further limitation concerns causal interpretation. A comparison of Adisutjipto Airport and YIA using a common network provides evidence about relative accessibility under the selected scenarios, but it does not independently identify the historical causal effect of relocation. A stronger historical evaluation would require comparable pre-relocation and post-relocation data and an analytical strategy capable of separating relocation-related changes from broader transportation and land-use developments.

Future research could address these limitations by integrating historical GIS datasets, observed travel-time information, public transportation schedules, and passenger surveys. Such an extension would enable researchers to distinguish changes in objective spatial accessibility from changes in perceived accessibility and to examine how travel costs and socioeconomic characteristics influence the experience of airport access. With suitable data and an appropriate

design, this approach could provide a more comprehensive assessment of the distributional and behavioral consequences of airport relocation.

CONCLUSION, IMPLICATIONS, AND FUTURE RESEARCH

Conclusion

This study provides a GIS-based framework for evaluating the spatial accessibility implications of airport relocation by comparing Adisutjipto Airport and Yogyakarta International Airport (YIA) across consistent geographical origin zones. By integrating network travel time, network travel distance, service-area analysis, and opportunity-based accessibility measures, the study offers a multidimensional approach to understanding how airport location interacts with transportation networks and the spatial distribution of population and economic activities.

The central conclusion is that airport accessibility should be understood as a geographically differentiated outcome rather than a uniform consequence of infrastructure development. The illustrative comparative results suggest that relocation may create different accessibility conditions across the region, with some origin zones potentially benefiting from their proximity to YIA while others may experience longer access journeys than under the former airport-location scenario. This pattern emphasizes that the implications of airport relocation depend on the geographical distribution of origins, the configuration of the transportation network, and the availability of effective connections to the airport.

The study also highlights the importance of distinguishing between network-based accessibility and opportunity-based accessibility. Travel time and distance provide direct measures of the burden associated with reaching an airport, whereas opportunity-based indicators capture the interaction between travel impedance and the distribution of relevant destinations or activities. These measures are complementary and should be interpreted together to obtain a more comprehensive assessment of regional accessibility. This approach is consistent with the conceptual foundations of accessibility research, which emphasize the interaction between transport systems, land use, and the opportunities available at different locations (Geurs & van Wee, 2004; Hansen, 1959).

Furthermore, the proposed analytical framework demonstrates the value of combining spatial analysis with statistical testing. GIS enables the identification of geographical patterns and differences in access conditions, while statistical analysis provides a structured means of evaluating whether observed differences across origin zones are consistent with the proposed



hypotheses. The integration of these methods can support a more transparent and reproducible assessment of airport accessibility than relying on geographical distance or descriptive observations alone.

Nevertheless, the interpretation of airport relocation effects depends on the comparative design. A comparison of the two airport locations using a common contemporary transportation network identifies their relative accessibility under the selected network assumptions. It does not, by itself, establish the full historical causal effect of relocation. A comprehensive assessment of historical change requires comparable data from before and after relocation, together with a strategy for distinguishing relocation-related effects from changes in road infrastructure, public transportation services, and land-use patterns. This qualification is particularly relevant given earlier research examining the implications of airport relocation for the transportation network in the Special Region of Yogyakarta (Fitrada et al., 2019).

Overall, the study contributes a spatially explicit approach to airport accessibility assessment and provides a methodological basis for identifying geographical areas that may require improved transportation connections. Its practical value lies in supporting evidence-based decisions concerning airport access, public transportation integration, and regional transport planning. The magnitude and statistical significance of the conclusions, however, must ultimately be established using verified spatial data and empirical results.

Theoretical Implications

This study contributes to accessibility research by operationalizing the relationship between airport location, transportation networks, and the spatial distribution of opportunities through a combination of GIS-derived indicators. Rather than treating accessibility as a single measure of proximity, the framework distinguishes between network-based impedance and opportunity-based accessibility. This distinction is consistent with Geurs and van Wee's (2004) argument that accessibility measures should reflect the purpose of the analysis, the characteristics of the transport system, and the distribution of land-use opportunities.

The first theoretical implication concerns the spatially differentiated nature of accessibility. Airport relocation can alter the relative geographical advantages of origin zones without necessarily producing a uniform regional improvement. This perspective extends the application of accessibility concepts to the evaluation of major transport infrastructure



relocation, where the spatial consequences may differ across locations depending on their relationship with the new infrastructure and connecting networks.

The second implication concerns the integration of network-based and opportunity-based accessibility measures. Network travel time and distance are useful for describing the direct burden of airport access, but they do not fully represent the potential for interaction between locations. Opportunity-based indicators provide an additional perspective by incorporating the distribution of population, employment, or other relevant destinations. The combined framework therefore supports a broader interpretation of accessibility that connects transportation impedance with spatial opportunity, following the conceptual tradition established by Hansen (1959).

The third implication concerns methodological transparency in spatial accessibility research. By applying consistent origin zones and comparable network assumptions to both airport locations, researchers can reduce inconsistencies arising from different geographical units or measurement procedures. The framework also clarifies the distinction between comparing alternative airport locations and estimating historical causal effects. This distinction strengthens the interpretation of accessibility research by ensuring that conclusions remain aligned with the evidence provided by the research design.

Practical and Policy Implications

The findings have several potential implications for airport-access planning and regional transportation policy. First, transport planners should identify origin zones that experience relatively high access times or limited network connectivity. Spatial accessibility maps can be used to identify locations where improvements in road connections, feeder services, or public transportation may reduce the burden of reaching the airport. Rather than applying uniform interventions across the region, planners can prioritize areas where the combination of travel impedance and population distribution indicates a substantial accessibility disadvantage.

Second, public transportation planning should emphasize service integration rather than infrastructure availability alone. The effectiveness of airport access depends on the continuity of the passenger journey, including connections between residential areas, local transport services, intercity services, and the airport. Improvements in service frequency, transfer coordination, timetable integration, and first-mile and last-mile connections may improve practical accessibility, particularly for users who do not have access to private vehicles.



Third, airport accessibility should be incorporated into regional land-use and transportation planning. The geographical distribution of residential areas, employment, tourism, and economic activities may influence the number of people affected by changes in airport access. By combining network travel indicators with population and opportunity-based measures, policymakers can evaluate whether transportation improvements address the needs of areas with substantial travel burdens or limited access to relevant opportunities.

Fourth, accessibility assessment should consider both efficiency and distributional outcomes. Reducing average travel time is a useful objective, but regional averages may conceal substantial differences between origin zones. Policymakers should therefore examine the distribution of access times and the geographical characteristics of areas experiencing relatively poor access. Where reliable socioeconomic data are available, further analysis may identify whether particular population groups face disproportionate access burdens.

Finally, GIS-based accessibility modelling can serve as a decision-support tool for evaluating alternative transportation scenarios. Planners can compare potential changes in road connections, public transportation routes, service frequency, and intermodal integration before implementing interventions. Such applications would enable regional authorities to assess not only whether a proposed intervention improves accessibility overall, but also where the expected benefits are geographically concentrated.

Limitations and Future Research

Several limitations provide opportunities for future research. First, the accuracy of network-based accessibility estimates depends on the quality and temporal consistency of the road-network data, travel-speed assumptions, and traffic information. Where observed travel times are unavailable, modelled estimates may not fully represent actual travel conditions, particularly during peak periods. Future studies should incorporate time-dependent traffic data, observed passenger travel times, and alternative travel scenarios to improve the reliability of estimated accessibility measures.

Second, the availability and quality of public transportation data may limit the assessment of multimodal airport accessibility. Information about routes, service frequency, operating hours, waiting times, and transfer conditions is necessary to evaluate the complete access journey. Future research could integrate road-network analysis with public transportation schedules and



multimodal routing models to examine how the combination of transport modes influences accessibility across different origin zones.

Third, the study's spatial comparison should be distinguished from a historical causal evaluation. A common-network comparison provides a consistent assessment of alternative airport locations, but it cannot independently identify the full effect of relocation over time. Future research should construct comparable pre-relocation and post-relocation datasets and consider suitable quasi-experimental or longitudinal designs where data and assumptions permit. Such an approach could help separate the implications of airport relocation from changes in transport infrastructure, congestion, and regional development.

Fourth, opportunity-based accessibility measures depend on the selection of opportunities, geographical aggregation, and the specification of the impedance function. Future studies could compare alternative accessibility formulations, including different distance-decay functions and population-weighted measures, to determine whether the findings are robust to alternative assumptions. Analyses using finer spatial units may also reveal differences that are obscured when accessibility is calculated at the administrative-area level.

Fifth, the present GIS framework primarily evaluates objective spatial accessibility. It does not, by itself, explain how airport users perceive accessibility or how travel costs influence their transportation decisions. Future research could integrate passenger surveys to examine perceived accessibility, generalized travel cost, transport-mode choice, and differences across income groups, trip purposes, and vehicle-ownership categories. Such an extension would require individual-level data and a clearly specified statistical model to test mediation or moderation effects.

Finally, future studies could investigate the relationship between airport accessibility and wider regional outcomes, including tourism activity, employment opportunities, business connectivity, and the distribution of economic benefits. These relationships should be investigated using suitable longitudinal or comparative data rather than inferred directly from accessibility maps. A broader analytical framework could help establish whether changes in spatial accessibility are associated with measurable changes in regional development and whether those changes are distributed equitably.

In conclusion, GIS-based airport accessibility analysis offers a useful foundation for evaluating the spatial implications of major transportation infrastructure decisions. By combining network impedance, geographical coverage, and opportunity-based measures, future research



can develop increasingly robust assessments of airport access and provide evidence to support more integrated, accessible, and spatially responsive transportation planning.

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