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Tool Selection for Detailed Accessibility Analysis Using GTFS Data: The Case of the Yamagata Urban Area

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Abstract

Accessibility, the ease of reaching a given destination from a given location, is a key indicator for identifying populations whose quality of life is constrained by limited access to essential goods and opportunities such as medical institutions. In Japanese geography, accessibility studies have rarely examined the relative effectiveness of analytical methods and tools, and the construction of data spanning multiple transport modes has remained difficult. This study employs the General Transit Feed Specification (GTFS), a public-transport data format that has become mainstream in recent years, to compute travel times that reflect actual departure and arrival times, including transfers, at a fine temporal resolution. Taking older adults' trips to medical institutions in the Yamagata urban area, a region with an exceptionally high car modal share and a proactive medical policy, as a case study, we compare three tools, ArcGIS Pro, OpenTripPlanner (OTP) and R5, in terms of travel-time accuracy and processing time. R5 proved both fast and generally accurate, whereas structural differences between the underlying routing algorithms (A-Star in OTP and RAPTOR in R5) produce systematic travel-time discrepancies that concentrate at specific origins and destinations. We organize these discrepancies into four structural factors and, to support quality control after tool selection, propose an open-source QGIS plugin that automatically flags origins and destinations requiring inspection.

1. Introduction

1.1 Background

Accessibility is an index that quantitatively evaluates the ease of approaching a particular place from a given location. Clarifying accessibility means identifying the groups whose quality of life is placed in a disadvantaged state because their ability to reach goods and activity opportunities essential to daily life is impaired; in geography it is frequently evaluated through indices such as the ease of reaching medical institutions or grocery stores.

As challenges for accessibility research in Japanese geography, Sekine (2018) and Tanimoto (2020) have noted that the effectiveness of different analytical methods and tools has not been sufficiently examined, and that it is difficult to construct data spanning multiple transport modes. In these prior studies, when measuring the travel time to a destination, either (a) the travel distance was divided by an average speed, or (b) the analysis was performed at a few fixed clock times; in either approach it is difficult to derive accurate travel times. This study therefore uses GTFS, a timetable-oriented data format used by services such as Google Maps, to carry out calculations that reflect actual conditions for each fine-grained departure/arrival time while also accounting for transfers.

Overseas, research examples using GTFS data already exist, such as the work of Lee and Miller (2018). In Japanese geography, however, the only example utilizing GTFS data is Kasahara et al. (2021), which analyses spatio-temporal patterns of delay times from the timetable data of the Sendai municipal bus; there is no comparable case that uses GTFS-format data to analyze accessibility.

This research makes it possible to perform accessibility analysis on data spanning multiple transport modes, which has been difficult to handle in conventional Japanese geography, and is also expected to enable examination of the effectiveness of the tools themselves.

1.2 Related Work and Research Problem

Regarding tools capable of route searching with GTFS, Higgins et al. (2022) compared several tools for Toronto, Canada, and empirically demonstrated the existence of "algorithmic dependence," whereby different results arise from the same data. That study, however, targeted a municipal administrative division in which GTFS was developed uniformly by a single operator, and it did not examine the behavior under the route-network conditions of Japanese regional urban areas, where the GTFS of multiple operators coexists and the service frequency is only one or two buses per hour even on major routes. Moreover, it concluded with the normative recommendation that analysts "should be careful in tool selection and result interpretation," without presenting a concrete mechanism to implement such care. With the aim of verifying the accuracy of the "travel time" of trips made by public transport and thereby improving the accuracy of accessibility analysis, this study compares tools on Japanese GTFS data and, in addition, proposes concrete means for quality control of the analytical results.

1.3 Study Subject

As the study subject, we take older adults' visits to medical institutions. When driving becomes impossible, for example after a voluntary surrender of a driving license, the accompaniment of family members becomes essential, particularly in areas with a high car modal share and poor public transport. In order to pursue independent mobility in an ageing society with a declining birth rate, we focus on "public transport," examine effective analytical methods and the tools to be used in accessibility research, and aim to conduct analysis that is easier and more precise than existing methods.

As the study area, we selected the Yamagata urban area (Yamagata City, Kaminoyama City, Tendo City, Yamanobe Town and Nakayama Town) for three reasons: "the disclosure of public-transport data is advanced," "the car modal share is extremely high," and "the area is proactive in medical policy." In Yamagata Prefecture, the timetable data of all bus routes in the prefecture are published as open data. According to a person-trip survey conducted independently by Yamagata City in 2017, the car modal share in travel was 76%, far exceeding that of other urban areas, while the combined modal share of bus and rail was only 3%. In addition, since 2013 Yamagata City has set out a vision of an "advanced health-and-medical city," leveraging its strength in abundant medical resources, and has been strengthening initiatives to utilize these resources.

2. Tools for GTFS-Based Accessibility Analysis

2.1 Accessibility Measures and Travel Time

Measures of accessibility can be divided into "relative accessibility," which expresses the ease of reaching one specific point from a given point, and "integral accessibility," which expresses the ease of reaching all goods and activity opportunities within an area (Tanimoto, 2020). As relative accessibility, there are proximity or threshold-based measures indicating whether a facility exists within a particular distance, and the minimum-travel-time measure indicating the minimum distance/time to the nearest service. As integral accessibility, there are the cumulative-opportunity measure, which counts the number of opportunities accessible within a fixed time, and the gravity-model measure, which considers weighting by distance and the attractiveness of locations; the latter in particular is widely used in geography for analyzing broad spatial structures and for analyzing behavior in which origins and destinations can be assumed (Higgins et al., 2022; Tanimoto, 2020).

To calculate these measures, it is necessary to compute the cost between points. The cost is either the distance along the route or the travel time. For cars and walking, the cost is often computed by distance, but for public transport, waiting times occur, so derivation by travel time rather than distance is preferable.

2.2 Evolution of Tools Used

Sekine (2018), who reviewed the progress of accessibility research using GIS, addressed the measurement of intermodal accessibility using ArcGIS. In that article it was stated that "the geospatial data of intermodal transport chains has a very complex structure and is also difficult to construct," but the widespread introduction of the "Standard Bus Information Format (GTFS-JP)," published by the Ministry of Land, Infrastructure, Transport and Tourism (MLIT) in March 2017, has activated the development of timetable data in an integrated data format nationwide. As of August 2025, seven prefectures, including Yamagata, are carrying out prefecture-led comprehensive development projects, and 727 operators across all 47 prefectures of Japan publish, as open source, data in the GTFS format that underlies the public-transport data model.

In prior research in Japan, Esri's tools have mainly been used for network analysis. Miyazawa (1998) carried out analysis using "ARC/INFO," the world's first commercial GIS software, and Sekine (2003) used "ArcView." The current software, ArcGIS Pro, also enables network analysis through the "Network Analyst" function. However, a challenge is that it is proprietary commercial software, and depending on the license held, an analytical environment may not be available.

Esri's current tool is "ArcGIS Pro (hereafter ArcGIS)," which also supports online and cloud-based use. This software, too, enables network analysis using the "Network Analyst" extension. In educational institutions it can be used without additional financial burden through the purchase of an educational license, but when used by individuals or corporations, an outlay of several hundred thousand yen is required. The fact that reproducibility cannot be ensured is a major challenge of using commercial software.

In addition to ArcGIS, tools capable of measuring travel time using GTFS data include open-source software (OSS) such as OpenTripPlanner (hereafter OTP), whose development was begun by volunteers in 2009, and R5, developed by Conveyal and adopting the RAPTOR algorithm established in Delling et al. (2015). The OTP used in this study is version 1, which has been developed independently. With the release of version 2 in 2020, the parts used for transport-research analysis, such as processing the large volumes of trip plans that researchers use, were removed. R5 is recommended as the successor software, and the current version of OTP is not suited to transport analysis. Note that version 2 of OTP adopts the same RAPTOR algorithm as R5.

Whereas ArcGIS requires road centerline data to be created or purchased, recent tools increasingly rely on OpenStreetMap (hereafter OSM) for the road network. OSM is a participatory geographic-information database that anyone can use and view freely and free of charge as open data, and through editing software it is also possible to correct and add to the road network. However, because it is data composed of lines and intersections, creating it from scratch involves more effort than data consisting only of centerlines.

Aspect	ArcGIS Pro	OTP (v1)	R5
Algorithm	Dijkstra	A-Star	RAPTOR
Road network	Centerline (create / purchase)	OSM	OSM
License / cost	Proprietary (paid)	OSS (free)	OSS (free)
OD matrix	Departure time only	Not provided	Optimized (very fast)
Time for ~1M OD	~10 min	~80 min	< 5 second
Reproducibility	Limited	Yes	Yes
Suitability for accessibility analysis	Low (accuracy issues)	Medium	High

Table 1. Comparison of the three tools and their underlying algorithms.

2.3 Algorithmic Differences and Structurally Divergent Elements

ArcGIS uses Dijkstra's algorithm, a classical method of route searching. Dijkstra's algorithm sequentially determines the shortest distance to each point in order of proximity from the origin, and can exhaustively obtain the shortest paths to all points. On the other hand, when the destination is clear, it includes computation to unnecessary points, so there is much waste in the computational process. OTP uses the A-Star method, which adds to Dijkstra's algorithm a minimum estimate of the remaining time, namely "at least how long it will take from the current point to the endpoint," and prioritizes exploration in the direction of the destination. This makes it possible to obtain the shortest path as with Dijkstra's algorithm while enabling faster processing.

In OTP, the walking route to a stop and the public-transport route are dynamically combined and computed for each request. In contrast, the RAPTOR algorithm precomputes an access matrix for each origin and destination at the time of network construction. Especially when creating OD matrices, R5 can complete processing at overwhelming speed, providing a major advantage for analysis aimed at transport policy and urban planning.

Beyond the difference in processing speed, the two algorithms also differ in how they manage state and how they handle constraints, and for some origin-destination data they can produce different results. Specifically, the elements in which the difference between the two algorithms appears in the results can be organized into four points.

The first is the difference in the boundary of stop access. In R5, when searching for the nearest stop from an origin or destination, it first searches for stops within 300 m, and if no route is found there, it searches for stops in the area up to whichever is shorter: the configured snappable distance range or the walking time. In other words, if the analysis is performed with a walking limit set to 500 m and a two-hour limit, and an itinerary taking 1 hour 50 minutes is found at a stop within 300 m, an itinerary that reaches a stop 500 m farther away in 50 minutes is not prioritized. Therefore, if there is an important stop, located between 300 m and the walking-limit distance from the specified origin or destination, from which many route systems depart and arrive, the situation arises in which the route from that stop is not selected. Because OTP actually traces the street network for each request, such a situation does not occur. Note that the value of 300 m cannot be changed by user settings under R5's specifications; changing it requires independently modifying and building the source code of R5, which is open source. The second is the upper limit of travel time. R5 immediately discards candidate routes that exceed this limit during computation, whereas OTP continues the search as long as the accumulated travel time remains within the limit. Therefore, long-distance routes that are right at the limit may disappear from R5's results but remain in OTP's results.

The third is the handling of U-turns on the same route. In the A-Star method, even when the same stop is reached at different times, these are treated as distinct states, so unnatural routes that combine an outbound and a return trip on the same route can remain in the results. In the RAPTOR algorithm, only the earliest arrival time is retained for each stop and the shortest combination is judged, so such routes are not retained.

The fourth is the difference in the transport mode prioritized in route searching. In the A-Star method, using the minimum estimate of the remaining time, namely "at least how long it will take from the current point to the endpoint," states that expand toward the destination are selected in order. This estimate is often computed as "the straight-line distance to the endpoint divided by the maximum available travel speed," and when the route network includes rail (around 80 km/h), the remaining time is estimated to be small even for routes that could be completed by bus alone, so there is a tendency for exploration in the rail direction to be prioritized. Because the RAPTOR algorithm updates the arrival-time table to all stops simultaneously without looking at the distance to the destination, such directional bias does not occur.

These differences in the four elements arise from the "algorithmic dependence" pointed out by Higgins et al. (2022), and tend to appear concentrated at specific origins/destinations and time periods. In the next chapter, we verify how these differences appear under the route-network conditions of Japanese regional urban areas and consider responses according to the results.

3. Empirical Study in the Yamagata Urban Area

3.1 Analysis Methods

In practice, we verify two points when each tool is used: "the accuracy and tendency of travel times" and "processing time." Three tools, ArcGIS, OTP and R5, are used for the analysis. R5 is provided only as an engine, so an operating tool must be prepared separately. In this empirical study, we verified using "R5R," which uses the R language and has the most functionality among the tools.

First, we compare the travel times between stops of rail-only, bus-only and both, within the study area, derived by the three tools while varying the arrival time minute by minute. Because the time differences arising from differences in how roads and stops are connected do not have an effect, pure travel times for each transport mode can be obtained. We check whether the results are computed accurately by manual calculation and by route-search software (Ekispert). Next, we similarly derive the travel times between each medical institution and the standard regional mesh used in the Japanese census, which is set at 125 m intervals.

To strictly compare the difference in results between the two tools, it is necessary to align parameters such as walking speed, walking limit and travel-time limit. However, OTP specifies walking speed in meters per second and the walking limit as a distance (in meters), whereas R5 specifies walking speed in kilometers per hour and the walking limit as a time (in minutes), so it is difficult to make the settings completely identical between the two tools. For example, since the definition of a transport-disadvantaged area in MLIT's "Handbook for Regional Public Transport Development" is 500 m or more from a stop, if one wishes to specify a travel distance of 500 m, then in order to specify 500 m as an integer number of minutes one must specify a walking pace such as 50 m, 100 m or 125 m per minute, but in any of these cases the value becomes indivisible when specifying the walking speed in meters per second in OTP. In this study, we set the same conditions by setting the walking speed to 4.8 km/h and the walking limit to 7 minutes, or 560 m.

As GTFS data, we prepared data for all public transport in the study area: the community buses of the five municipalities, Yamako Bus, and JR East. For the six operators other than JR, we downloaded and used data as of 1 October 2025 from the "GTFS Data Repository" operated by the Association for Infrastructure Geospatial Information Distribution (AIGID). For JR, since no open data exists, we created GTFS-format data from timetable data using the "Nishizawa Tool," which can create GTFS-format data with a Microsoft Excel macro and was developed by Mr Akira Nishizawa of the Center for Spatial Information Science, the University of Tokyo. Initially, the positions of the stops were created using the National Land Numerical Information (railway data), but because a phenomenon occurred in which no route could be found for bus-rail transfers, we aligned the positions of the station point data with the positions of the stop data in OSM. As road data, for OTP and R5 we used the OSM data for the whole Tohoku region as of 1 October 2025, published by GEOFABRIK, cut out to only the necessary area using the command-line Java application "osmosis." For ArcGIS Pro, we purchased and used the road-centerline data of the Digital Map (Basic Geospatial Information) published by the Geospatial Information Authority of Japan (GSI) for the target area.

3.2 Computation Time and Travel-Time Agreement

Regarding processing time, for a computation with about one million origins and destinations, ArcGIS Pro took about 10 minutes, OTP about 80 minutes, and R5 within 5 seconds. OTP takes time because it computes each origin-destination route without efficiency optimizations, and because the software does not provide OD computation, processing large volumes of data is difficult. R5 is optimized for OD computation, and our result is consistent with the report in Higgins et al. (2022) that it is the only tool capable of creating an OD of 100,000 by 100,000 within 24 hours.

Regarding the travel times of OTP and R5, when about 100,000 records were compared, the median of the differences was about 2 minutes, the correlation coefficient was 0.9 or higher, and 93.2% of the ODs fell within an error of 5 minutes. This is consistent with the high correlation of travel times between the two tools reported by Higgins et al. (2022) in their analysis of North American cities, and shows that a similar tendency can be confirmed for Japanese GTFS-JP data and regional urban-area route networks as well. The same close agreement appears in the pure inter-stop comparison shown in Figure 1: across 6,124 stop-to-stop ODs, the correlation between OTP and R5 was 0.971, and 93.2% of the pairs fell within a 5-minute error.

ArcGIS also has sufficient processing speed, although not to the extent of R5; however, in creating an OD matrix only the departure time can be specified, and if one wishes to specify the arrival time the computation must be redone from the service area, so it is difficult to use it directly for large-scale processing targeting arrival times.

Moreover, in ArcGIS, the travel times matched those of OTP and R5 for only just under 50% of the data (Figure 2): for the 2,250 inter-stop pairs, the correlation between R5 and ArcGIS Pro was only 0.569, just 47.6% fell within a 5-minute error, and ArcGIS Pro was on average 17.0 minutes slower. As a cause of the low agreement rate, for OD pairs in which OTP or R5 use different departure/arrival stops or routes depending on the time period, ArcGIS Pro in most cases failed to derive the route with the shorter travel time. In addition, for routes requiring transfers between somewhat distant stops, such as transfers between a railway station and a bus stop, there were many patterns in which derivation was not achieved. Furthermore, the data for which ArcGIS showed the shortest travel time among the computation results of the three tools were extremely few, and in all of them boarding occurred from alight-only stops, where boarding is originally not permitted on the GTFS data. This is thought to be a phenomenon that occurs because ArcGIS, rather than using GTFS data as is, converts it into an internal public-transport data format, which causes the loss of data such as transfer information and boarding/alighting restrictions. Therefore, ArcGIS has to be excluded in terms of accuracy, and we concluded that it is appropriate to adopt either OTP or R5.

For the pure inter-stop travel times, we excluded ArcGIS, which never produced the fastest value among the three tools, and exhaustively cross-checked the fastest values computed by OTP and R5 against values obtained manually with the commercial route-search service Ekispert. Travel times agreed for just under 70% of the ODs; for about 25% the tools were faster, and for the remaining 5%-plus Ekispert was faster. The cases in which Ekispert was faster fall into two types. The first is cases in which the tools could not use a service departing on the minute. This stems from the fact that, when the origin point and the boarding stop do not coincide exactly, a number of seconds proportional to the distance is added to the departure time; for example, boarding a 15:00:00 train would require departing at 14:59:59, so a 15:00:00 instruction is judged as non-boardable. This is resolved by computing the fastest value over a few surrounding minutes: using the fastest value over the preceding five minutes reproduced exactly the same travel time as Ekispert, so the tool computations cannot be regarded as erroneous. The second is cases requiring a transfer that exceeds the walking limit, observed at a few locations involving rail-to-bus or bus-to-bus transfers. Because Ekispert registers the feasibility of movement on a per-stop basis rather than by distance or time, it permits such common-sense transfers; reproducing this in OTP or R5 requires either preparing GTFS data that defines the transfer time or relaxing the walking limit. Overall, with appropriate pre-processing and parameter settings, OTP and R5 derive travel times consistent with an external route-search service, confirming the accuracy of the proposed approach.

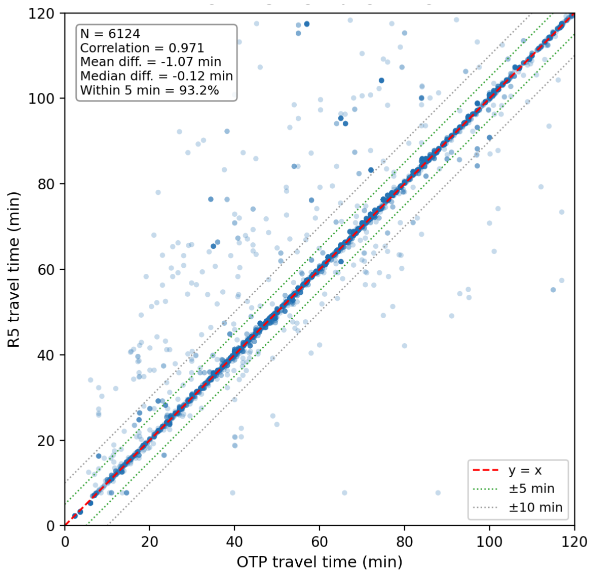

Figure 1. OTP versus R5 travel times between stops.

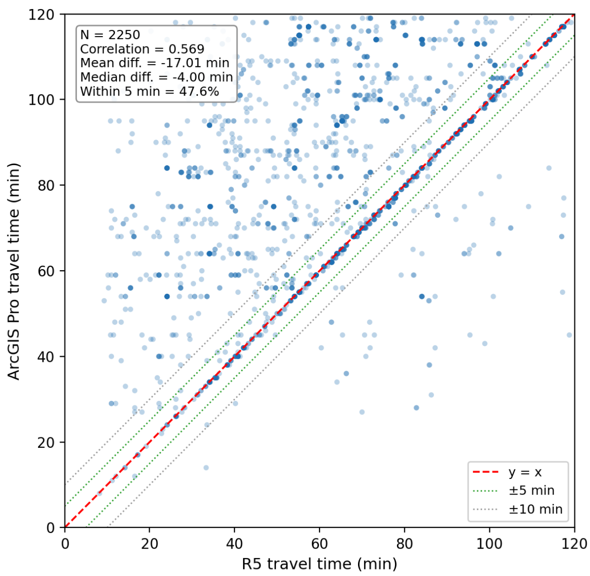

Figure 2. R5 versus ArcGIS Pro travel times between stops.

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3.3 Characteristics of Origins/Destinations Producing Discrepancies

In the comparison of OTP and R5, ODs with a difference of 5 minutes or more occurred for 6.8%; the breakdown was 5.1% (314 records) where OTP was shorter and 1.6% (101 records) where R5 was shorter. Excluding non-structural cases in which the difference between the two tools disappears by shifting the clock time by a few minutes (cases arising from slight differences in the walking route), about 125 records on the side where OTP was shorter and about 60 records, corresponding to 1%, on the side where R5 was shorter remained as structural differences. Furthermore, since a small number of cases in which the difference was 30 minutes or more also occurred, we examined in detail under what conditions they arise. These could be confirmed in a form corresponding to each of the four elements organized in Chapter 2.

Many of the cases in which a longer travel time was computed on the OTP side corresponded to the difference in the transport mode prioritized in route searching. As a result of exploration being prioritized in the direction of a railway station near the origin, there were cases in which the discovery of a transfer route with a winding shape that could be completed by bus alone was not in time before the search was terminated, and a long-duration route using only a direct bus was returned. In addition, as cases corresponding to the handling of U-turns on the same route, there were also observed cases in which OTP retained in its results a route combining an outbound and a return trip on the same route.

On the other hand, many of the cases in which a longer travel time or unreachability was computed on the R5 side corresponded to the difference in the boundary of stop access and to the upper limit of travel time. Specifically, they were concentrated at origins/destinations whose nearest stop is located on the boundary line of the walking limit, or at long-distance origins/destinations whose travel time is right at the upper limit. This arises because R5, through precomputation, fixes the set of accessible stops and the upper limit of travel time, so routes that slightly exceed the boundary line are excluded from the search targets. Many such cases can be absorbed by taking advantage of R5's high speed to perform computations continuously at one-minute intervals and adopting the minimum or representative value in that time period. Since R5R has a built-in function that computes all travel times for a certain duration from a specified time and returns a representative value such as the minimum or the median, this can be carried out at no additional computational cost.

However, cases in which the optimal stop is located at a position greatly exceeding the walking limit, or cases of long-distance routes greatly exceeding the travel-time limit, cannot be resolved by shifting the clock time alone. Moreover, these result differences do not occur randomly but tend to appear concentrated at specific origins/destinations and time periods, and it became clear that carefully observing the stops at which errors occur leads to an improvement in the validity of the results. Therefore, resolution can be expected by correcting the road-network data and the stop transfer data of the target points. If this is still difficult, judgements such as loosening the parameters of the walking limit or travel-time limit themselves, or changing the destination point, become necessary.

From the above, although the adoption of R5 is appropriate from the viewpoint of computation speed, because the results can vary for each origin/destination corresponding to the four elements, it became clear that it is desirable to use the results of OTP to grasp these in advance and to exclude, as far as possible, the conditions that cause them.

4. Proposal of a QGIS Plugin for Diagnosing Anomalous Origins/Destinations

As seen in Chapter 3, although the travel times of OTP and R5 broadly agree as a distribution, result differences tend to concentrate at specific origins/destinations in a form corresponding to the four elements organized in Chapter 2. If these origins/destinations are not grasped when adopting R5 to compute accessibility, problems arise in the use of the analytical results. On the other hand, checking origins/destinations one by one by hand is not realistic at a practical scale where the analysis targets thousands to tens of thousands of meshes or facilities. To address this problem, this study proposes, as software, an open-source plugin that runs on QGIS.

This plugin receives as input the GTFS data of the target area and the travel-time computation results of OTP and R5 respectively, and aggregates, taking the origin/destination as the unit, the result differences and the bias in reachability between the two tools. The output reveals the origins/destinations requiring inspection. The plugin does not directly determine which tool is correct; it only presents, as inspection targets, the origins/destinations whose result differences are abnormally large. For origins/destinations that surface as inspection targets, it is designed so that one can check, among the ODs around that origin/destination, those with large result differences, the route systems composing those routes, and the stop information on the GTFS side. The analyst who has observed the result differences can obtain, within a single GIS environment, a starting point for distinguishing whether the problem stems from the GTFS data, the tool, or the configured parameters.

The origins/destinations revealed by this plugin are considered to correspond to one of the four elements organized in Chapter 2. For example, an origin/destination for which R5 produces no result is highly likely to be located at the boundary of the difference in stop access or at the boundary of the upper limit of travel time, and an origin/destination for which a longer travel time is computed only on the OTP side is highly likely to be affected by the difference in the transport mode prioritized in route searching. By correcting the road-network data and the stop transfer data for these errors, analysis that more appropriately selects the shortest route becomes possible.

Through these operations, by improving the accuracy of travel-time measurement using the tools, the approach is expected to be utilized as a guideline for data-quality improvement not only by researchers but also by local-government staff engaged in public-transport planning and by transit operators that publish GTFS data. Through the implementation and release of the plugin, we aim to facilitate the participation of practitioners conducting GTFS-based accessibility analysis and to develop a foundation that supports quality control after tool selection.

5. Accessibility Changes Associated with Service Reductions

Exploiting the speed of R5, we computed the cumulative-opportunity measure, which is widely used in geographic accessibility analysis. Specifically, over the consultation hours we continuously derived the travel times from the 8,519 inhabited residential meshes in the study area (at 125 m intervals, excluding meshes with zero total population) to the 146 medical institutions offering internal medicine, and at each location weighted the number of institutions reachable within 60 minutes by the population aged 65 and over. Using this framework, we compared accessibility before and after a reduction in Yamako

Bus services. The operator reduced services in some districts during 2023-2024 and, in April 2025, abolished two routes and shortened one route within Yamagata City, amounting on a GTFS trip-count basis to an approximately 21% reduction in services on both weekdays and weekends/holidays. Comparing the reachability of September 2022 with that of 2025, more than 4,000 older adults had completely lost access to any medical institution reachable within 60 minutes. Examining the change at each origin, the points whose number of reachable institutions increased, owing to route consolidation or to additional transfer patterns, amounted to only 456 points (9,115 people) within the 60-minute range, whereas at 2,806 points (58,417 people), concentrated mainly along the bus routes, the number of reachable institutions decreased. Because the rail timetable was almost unchanged, these changes are attributable to the bus-service reduction; both the reachable population and the number of reachable institutions per facility fell by 30-40% over the three years. Moreover, when accessibility was evaluated by the conventional method of counting the population residing within a fixed-distance buffer of the stops, the reachable population was overestimated by roughly 20-30%. Continuous, high-speed analysis with R5 thus provides a basis for finely matching demand and supply, both when a service reduction is under consideration and after its implementation, and for quantitatively verifying the validity and the area of impact of such plans.

6. Conclusions

In this study, we compared the accuracy and processing time of travel-time derivation using GTFS for three tools, and clarified that R5 is fast and generally highly accurate. By adopting R5 to perform accessibility analysis, analyses that have conventionally been difficult, such as continuous time-of-day evaluation and reachability evaluation according to the start time of medical consultations, become feasible within practical processing times.

On the other hand, it was also found that, owing to the structural differences from the algorithms used in conventional tools such as OTP, result differences arise at specific origins/destinations. The QGIS plugin proposed in this study plays a role in supporting quality control after tool selection by automatically extracting such origins/destinations.

In the future, by using highly accurate public-transport travel-time data, the presentation and evaluation of new measures in accessibility research can be expected.

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