



Linking Public Transport Provision to Functional Regions: Evaluating Transport–Commuting Alignment in Estonia

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Abstract. This study analyses the alignment between Estonia’s public transport (PT) network and functional regions derived from daily commuting related travel. The aim of the research is to analyse whether public transport services provide sufficient levels of access to local commuting centres based on openly available GTFS data and functional regions defined from commuting statistics. The analysis across 21 functional regions reveals that while PT services cover nearly the entire country, alignment with designated commuting centres is considerably lower. 365 localities (44.5%) have their primary PT destination aligned with their designated commuting centre. 566 localities (69.1%) meet the minimum level of daily access to their commuting centre defined as at least one morning peak connection to the centre and one evening peak return. Population-weighted analysis shows that 12.4% of residents outside commuting centres do not have sufficient PT access to their centre for daily commuting. Travel times to the commuting centre are long, with the median PT journey time from localities with direct connections being 43 minutes. The results reveal the misalignment between commuting-based functional regions and PT provision organised in respect to administrative units, indicating priorities for better integrating PT planning with commuting patterns.

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BoK Concepts. [AM11] Network Analysis; [FC3] Geoinformation and Society

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1 Introduction

Improving accessibility by public transport (PT) is key to reducing private car dependence for daily commuting and supporting the transition towards sustainable mobility. Work-related travel represents the most regular and spatially structured form of mobility and therefore offers the greatest potential for replacing private car trips with PT usage. The EU has placed modal shift from private vehicles to PT at the core of the European Green Deal and the Sustainable and Smart Mobility Strategy, which stress the importance of improving transit accessibility in reducing car usage (European Commission, 2019; European Commission, 2020).

Estonia has set ambitious targets to increase the modal share of sustainable transport (walking, cycling, public transport) to 55% by 2035 (Ministry of Economic Affairs and Communications, 2021). An ongoing public transport reform aims to help fulfil the targets as Estonia’s PT modal share currently remains low at approximately 19% (Estonian Transport Administration, 2023). A fundamental question underlying these policy challenges is whether Estonia’s PT network aligns with people’s observed travel patterns. PT services often fail to keep pace with changing spatial commuting patterns, particularly as functional labour market regions expand beyond existing administrative boundaries. The most pressing issues are faced by residents of sparsely populated rural areas where coverage and service frequency remain limited (Farrington and Farrington, 2005; Lucas, 2012).

PT planning in Estonia has largely been organised along administrative county structures, which do not necessarily reflect daily commuting patterns. The ongoing national spatial planning process “Eesti 2050” recognises this potential misalignment by defining 21 functional regions based on observed commuting patterns, assigning each locality to a dominant commuting centre.

This study addresses the issue of misalignment between the PT network and observed daily commuting patterns by assessing whether PT connections from each locality are oriented towards its designated commuting centre and whether a minimum level of access enabling commuting using PT to the commuting centre is provided. By linking service orientation and travel time analysis to functional commuting patterns, the study contributes to GIS science research on transport land use alignment and provides insights for Estonia’s national planning and sustainable mobility targets.

2 Data and Methods

2.1 Data Sources

The study combines two primary datasets. Public transport data in GTFS format from the Estonian Transport Administration provides scheduled PT information. GTFS is a standardised, open format containing information on all PT routes, stops, departure times, and timetables across Estonia. The analysis was based on a representative Tuesday (15 April 2025) to capture typical weekday service patterns, avoiding public holidays and atypical travel patterns.

Functional regions of Estonia were defined based on daily commuting statistics from Statistics Estonia, building on a methodology originally developed for the 2007 national commuting study. Each of the 840 localities was assigned to the commuting centre that attracted the largest share of its resident workers. Localities with the same commuting centre were then grouped into a single contiguous functional region, resulting in 21 functional regions each with a designated commuting centre. Tab. 1 summarises the two datasets.

Table 1. Data sources used in the analysis.

Dataset	Source	Description
Public transport services	Estonian Transport Administration	PT schedules in GTFS format. Data from 15 April 2025.
Functional regions	Statistics Estonia / Estonian Land Board	840 localities grouped into 21 functional regions including data on commuting flows

2.2 Methodology

The workflow used in the study consisting of seven steps is summarised as a flowchart in Fig. 1.

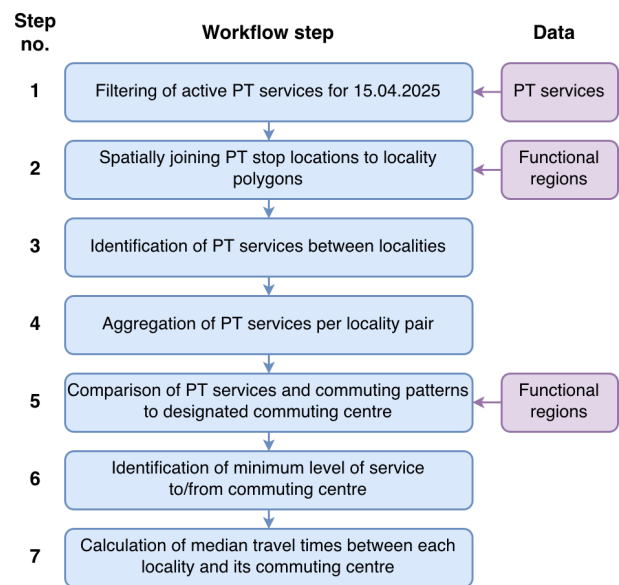


Figure 1. Flowchart of the study methodology. PT — public transport.

First, active services for the target date were identified from the GTFS dataset. Second, PT stops were spatially joined to locality polygons. Third, for each active trip, the sequence of localities traversed was extracted and all forward-direction locality pairs were generated: a trip through localities A→B→C→D yielded pairs A→B, A→C, A→D, B→C, B→D, and C→D, with each trip counted once per unique locality pair. Fourth, trips were aggregated by origin–destination locality pair to determine total daily services, the top PT destination for each origin locality, and the number of services connecting to the designated commuting centre. Fifth, for each non-centre locality, the top PT destination was compared to the designated commuting centre to assess alignment. Sixth, a minimum level of service was defined: a locality was deemed sufficiently served if at least one PT departure from the locality arrived at its designated commuting centre during the morning peak (07:00–09:00), and at least one return departure from the centre departed during the evening peak (15:00–19:00). Localities not meeting both conditions were classified as insufficiently served, regardless of total daily service frequency. Seventh, median travel times by PT to each locality's designated centre were calculated. Travel times were measured between representative stop pairs, defined as the stop within each locality with the highest number of daily services to the centre and the most-served arrival stop within the centre. The median was then calculated across all qualifying services connecting the two representative stops throughout the day.

2.3 Data and Software Availability

The GTFS data are publicly available from the Estonian Transport Administration at <https://peatas.ee>. The functional regions dataset is part of the ongoing “Eesti 2050” national planning process and is currently not publicly available. Analysis was conducted in RStudio and QGIS with assistance from Claude AI for code structuring. The full code and output datasets are available at <https://github.com/mahrtinh/transport-commuting-alignment-estonia>.

3 Results

3.1 PT Coverage and Alignment

Of Estonia's 819 non-centre localities, 776 (94.7%) have at least one outbound PT service on a typical weekday; only 43 localities (5.3%) with a combined population of 3,987 residents (0.3%) are entirely without PT services. Despite the broad coverage, connectivity with commuting centres is considerably lower. 365 localities (44.5% of non-centre localities) have their primary PT destination matching their designated commuting centre, and 170 localities (20.8%) have no direct connection to their centre.

Approximately 60% of Estonia's population lives within commuting centres themselves (primarily Tallinn and

Tartu) where the alignment question does not apply. Of the remaining 535,122 non-centre residents, 317,390 (59.3%) live in localities where PT services are aligned with commuting patterns, while 44,428 (8.3%) residents do not have a direct PT connection to their centre.

Considering the minimum level of service for access to the commuting centre, 566 localities (69.1%) have connections enabling a viable round-trip for daily commuting (Fig. 2). In population terms, 468,601 residents (87.6%) of the non-centre population live in localities where such a round-trip is feasible, compared to 66,521 residents (12.4%) who do not have access to PT services which enable daily commuting. Summary statistics are presented in Tab. 2.

3.2 Travel Time to Commuting Centre

Travel time to the commuting centre varies widely across the localities (Tab. 3; Fig. 3), with a median journey time of 43 minutes among localities with a direct PT connection. Of non-centre residents ($n=535,122$), 28.4% can access their centre within 30-45 minutes using PT. 23.4% have access times of 15–30 minutes while 17.8% have access times exceeding 60 minutes. Only 6.3% (33,960 residents) from 55 localities can access their centre within 15 minutes.

Functional Regions: Public Transport Connectivity to Commuting Centres

Full colour = morning (AM) & evening (PM) peak PT connections available | Lighter = no direct AM & PM connections | Hatched grey = no PT service

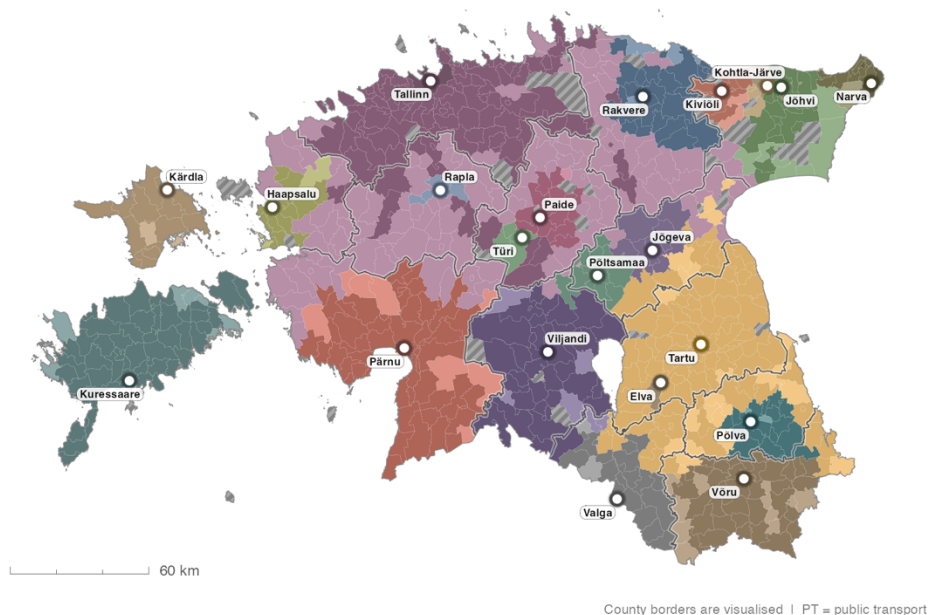


Figure 2. Public transport connectivity of localities to their designated commuting centres in Estonia. Each functional region is shown in a distinct colour. Full colour indicates localities with at least one PT departure arriving at the centre during the morning peak (07:00–09:00) and at least one return service during the evening peak (15:00–19:00).

Table 2. PT coverage and alignment statistics.

Metric	Count	Share	Population	Share of total
Total localities	840	100%	1,331,824	100%
Commuting centres	21	2.5%	796,702	59.8%
Non-centre localities	819	97.5%	535,122	40.2%
Non-centres with PT service	776	94.7% *	531,135	99.3% *
Non-centres with no direct PT service to centre	170	20.8% *	44,428	8.3% *
Non-centres with PT aligned with commuting	365	44.5% *	317,390	59.3% *
Non-centres with minimum level of service	566	69.1% *	468,601	87.6% *

* Proportion of non-centre localities (n=819)

Table 3. Distribution of travel time by PT from non-centre localities to their designated commuting centre.

Travel time to commuting centre	Localities	Share of localities	Population	Share of population
Commuting centre (N/A)	21	2.5%	796,702	59.8%
0–15 min	55	6.7% *	33,960	6.3% *
15–30 min	145	17.7% *	125,407	23.4% *
30–45 min	133	16.2% *	152,087	28.4% *
45–60 min	133	16.2% *	84,386	15.8% *
60–90 min	128	15.6% *	73,612	13.8% *
90+ min	55	6.7% *	21,242	4.0% *
No direct PT to centre	170	20.8% *	44,428	8.3% *

* Proportion of non-centre localities (n=819)

3.3 Spatial Patterns of Misalignment

The mapping of PT services and commuting patterns reveals distinct spatial differences (Fig. 4). The historical alignment of PT services along administrative county boundaries can clearly be seen. Large functional regions, such as Tallinn and Tartu, have expanded well beyond their county borders, while the PT network has not adapted. Some county centres (e.g. Rapla) have seen their

Median Travel Time to Commuting Centre

Typical PT journey time from each locality to its designated centre

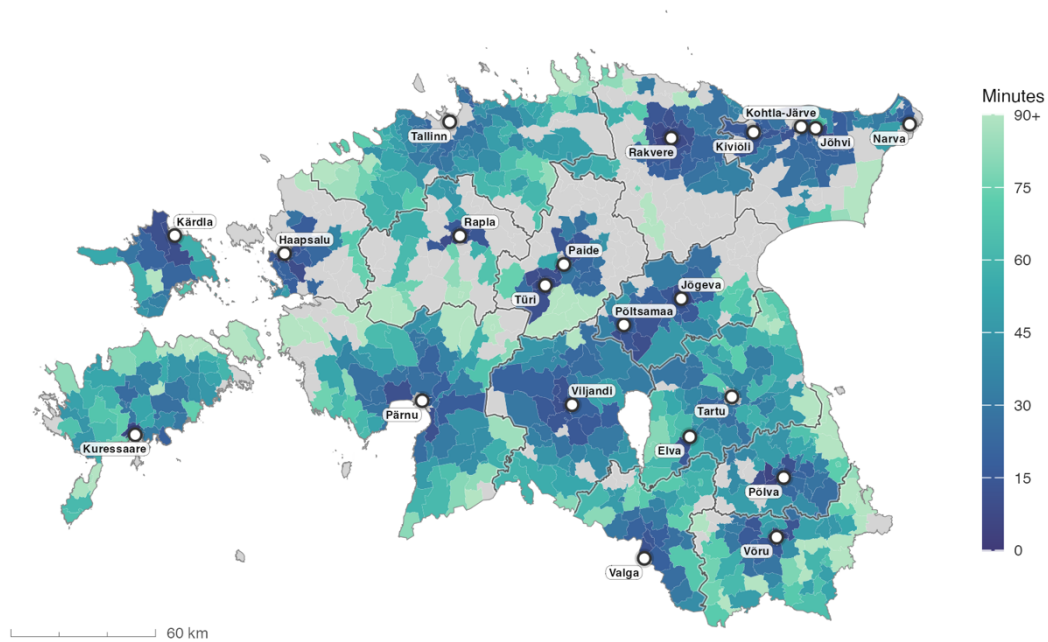


Figure 3. Median travel time (in minutes) to commuting centre by PT on a typical weekday. Grey localities have no direct PT connections to centre.

Alignment of Public Transport Services with Commuting Centres

Top three destination localities by number of services

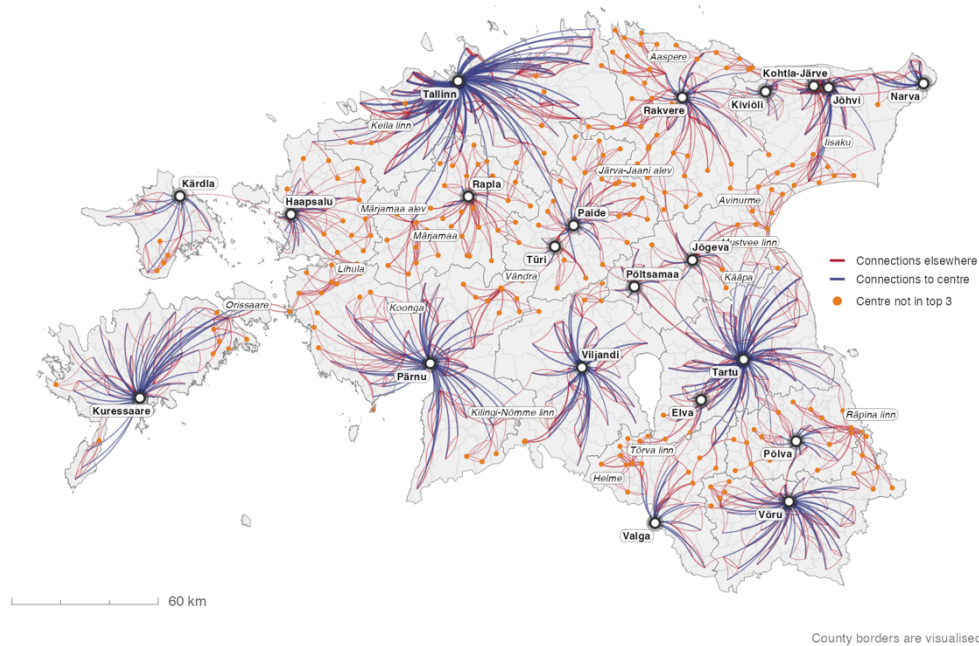


Figure 4. Alignment of PT services with commuting centres. Flow lines show the three most-served PT destinations from each locality, ranked by number of scheduled trips on the reference date. Orange points indicate localities whose designated commuting centre does not appear among their top three destinations.

functional hinterland diminish significantly, yet transport provision still reflects the historic administrative logic.

3.4 Regional Variation in Alignment

Regional alignment rates vary considerably across Estonia's 21 functional regions. Four smaller functional regions of Elva, Rapla, Jõgeva and Põltsamaa achieve 100% alignment due to their few non-centre localities all served primarily by routes oriented toward their designated centre. The Tallinn functional region has the lowest alignment rate at 20.0%, with only 41.6% of localities meeting the minimum round-trip service level. However, when weighted by population, these figures rise to 49.6% and 80.0% respectively, indicating that PT service is concentrated in the larger, more populated settlements while smaller peripheral localities remain poorly served. The next lowest alignment rates are found in Kiviõli (28.6%) and Jõhvi (38.9%).

In the functional regions of Võru and Haapsalu, alignment rates exceed round-trip feasibility rates (79.2% versus 77.1% and 88.2% versus 82.4% respectively) meaning that while the commuting centre is the primary PT destination for most localities, fewer have connections during both the morning and evening peak time periods. The opposite is observed in Põltsamaa, where all localities meet the minimum round-trip requirement yet only 72.7% are aligned with the centre, implying that some localities

are well connected to the centre at peak hours but use it as a secondary rather than primary destination.

4 Discussion

The finding that 44.5% of non-centre localities have PT services aligned with commuting patterns, and 69.1% meet the minimum level of PT service for daily commuting, points to notable misalignment between transport provision and actual commuting patterns. This likely reflects the historical structure of PT provision, where route networks were shaped according to administrative boundaries and settlement hierarchies rather than actual commuting flows. At the same time, the network structure reveals several important sub-centres that, while not designated commuting centres, provide essential everyday services to surrounding localities. Convenient PT connections to such local centres serve an important role in sustainable regional policy and should not be dismissed as irrelevant based solely on commuting data.

The markedly lower alignment in large functional regions (Tallinn 20.0% and Tartu 40.3%) compared to small compact regions such as Elva, Rapla, Jõgeva, and Põltsamaa (all 100%) indicates that misalignment is most visible in regions whose role as a significant national

commuting centre has grown most rapidly. Within such regions, the PT network simultaneously serves many cross-regional travel demands in addition to connections with the commuting centre. This has implications for how the alignment metrics should be interpreted. In large functional regions, the commuting centre may be well served by multiple routes from different directions, yet none of them individually exceeds trips to a local sub-centre causing the binary measure to underestimate accessibility. The population-weighted figures partly address this. In the Tallinn region, 80.0% of residents live in localities that meet the minimum service level for daily commuting, even though only 41.6% of localities do, indicating that PT provision is concentrated where population density is highest. This finding is consistent with broader evidence that rural and peripheral populations face disproportionate transport disadvantage (Farrington and Farrington, 2005; Lucas, 2012). Alignment rates in Võru and Haapsalu regions exceed round-trip feasibility rates, indicating that PT routes connect the right places but departure times do not consistently cover both peak periods. In these cases, simple timetable adjustments rather than network restructuring would be sufficient for increasing the usability of PT for commuting.

Several methodological limitations apply. Functional regions are defined by the largest commuting share. Where shares to two centres are similar, the workflow assigns a single destination, ignoring commuting to other centres. The analysis considers only direct PT connections meaning journeys requiring a transfer providing convenient access to commuting centres where no direct service exists are not captured. The results are based on a single reference date, and seasonal or weekly variation in service provision is not accounted for. Finally, GTFS data represent scheduled services and do not capture actual journey times, accessibility of stops, and last-mile connectivity.

The findings are relevant to Estonia's national spatial strategy "Eesti 2050" and the ongoing public transport reform by identifying the regions where misalignment is most pronounced and where changes in PT provision is most needed to increase the modal share of PT.

5 Conclusions

This study shows that notable misalignment exists between commuting patterns and the PT network in Estonia. While PT coverage is extensive, with 94.7% of non-centre localities having at least one weekday service, service orientation frequently does not correspond to designated commuting centres. Under half (44.5%) of non-centre localities have their primary PT destination

aligned with their commuting centre, and 20.8% lack any direct connection altogether. Of those with a direct connection, the median journey to the centre takes 43 minutes. 69.1% of non-centre localities with a population share of 87.6% meet the minimum service level for daily commuting, indicating that existing PT provision is concentrated in larger settlements. Nationwide, regional alignment rates range from 20.0% in the Tallinn functional region to 100% in the small compact regions of Elva, Rapla, Jõgeva, and Põltsamaa.

The findings point to concrete priorities for transport planning: reorganising PT routes to better align with primary commuting corridors and integrating PT planning more closely with the functional region framework. The GTFS-based methodology presented is replicable in other national contexts where commuting data and open GTFS feeds are available, offering a transferable approach to identifying misalignment between transport provision and spatial planning objectives. Future research should address the binary nature of the alignment measure by incorporating degree of alignment, accounting for transfer-based journeys, and considering PT connectivity to secondary commuting centres in addition to the primary designation.

Declaration of Generative AI in Writing

The authors declares that AI tools were utilised in the preparation of this manuscript for language editing, code structuring, and text structuring assistance. All scientific content, analysis, interpretation of data, and substantive conclusions are original work conducted by the authors.

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