TRANSPORTATION NEEDS AND CURRENT SERVICES IN MILLE LACS AND KANABEC COUNTIES AND THE 5-COUNTY EAST CENTRAL REGION

FINAL REPORT

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Small Minnesota communities have a tremendous number of existing assets: beautiful natural areas; essential built environments; economic strengths, and human capabilities to build upon community strengths, meet their challenges, and move toward their aspirations.

The Empowering Small Minnesota Communities (ESMC) program is a community-centered collaboration with the University of Minnesota to support small communities in becoming well-positioned to benefit from federal, state, and local investments.

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EXECUTIVE SUMMARY

For many communities in rural America, transportation access proves to be a substantial obstacle to healthy, sustainable living. The necessity of vehicle ownership creates significant barriers to accessing employment opportunities, affordable grocery stores, medical and social services, and personal recreation and social connections. In East Central Minnesota, the East Central Regional Development Commission (ECRDC) and Lighthouse Child & Family Services have initiated a collaborative effort to assess current transportation infrastructure and identify gaps between existing services and community needs. This regional collaboration brings together transportation providers, riders, regional authorities, and social service stakeholders in a concerted effort to understand and address this multifaceted issue that profoundly impacts quality of life in the region.

Through both qualitative focus group analysis of focus groups and quantitative assessment of existing transportation services, this report presents differences between needs and existing services for residents of Mille Lacs and Kanabec Counties. Our findings show a lack of East to West transit options, impacting quality of life as it relates to healthcare access, affordable grocery access, and social and recreational opportunities. The analysis of the focus group discussions highlights temporal service deficiencies, the differences in opportunities offered by medical and non-medical transportation, and nuanced relationships with rural volunteer driver networks.

The quantitative analysis revealed that transit availability in East Central Minnesota is uneven and needs some improvements to align with travel demand, with pronounced gaps between key cross-county city pairs like Cambridge and Princeton. County-level discrepancies are also found in terms of local/regional transit coverage. Results indicate that targeted expansions in service areas and transfer facilitation would more effectively address regional mobility needs than frequency increases alone.

Based on the findings of our analyses, we recommend four transit service improvements to address existing service gaps. These were specifically identified through the transit service gap analysis. However, they are consistent with the findings from the focus group discussions.

This work should support future considerations for service expansion by transit providers, legislative actions, and grant application processes for addressing transportation needs.

CHAPTER 1: INTRODUCTION

1.1 TRANSPORTATION PROVIDERS, SERVICE AREAS, AND HOURS OF OPERATION

The following transportation providers currently serve the five counties of Kanabec, Mille Lacs, Pine, Isanti, and Chisago of East Central Minnesota, or the ECRDC region:

- ➔ Timber Trails (General public transportation)
  - ◆ Weekdays, 7 AM - 6 PM
  - ◆ The predefined service area within Kanabec County, centered on Mora, extends approximately 10 miles to encompass Ogilvie and Braham
  - ◆ A weekly service to Cambridge
  - ◆ No service in northern and western Kanabec County
- ➔ Tri-CAP (General public transportation)
  - ◆ Weekdays 6 AM - 6 PM; Saturday 8 AM - 5 PM
  - ◆ The predefined service area within Mille Lacs County encompasses an area approximately 10 miles in extent, centered around the City of Milaca. The service also covers a 5-mile buffer south to Milaca along US-169 Highway, reaching the City of Zimmerman (Sherburne County)
  - ◆ No service in northern Mille Lacs County (Onamia, Isle, etc.)
- ➔ Arrowhead Transit (General public transportation)
  - ◆ Pine County (varying schedule by route)
    - Multiple within- or cross-county routes along I-35
    - Pine City Dial-a-Ride (DAR)
  - ◆ Chisago County (varying schedule by route)
    - Multiple within- or cross-county routes along I-35 and US-8
    - North Branch DAR and Center City-Wyoming flexible route
  - ◆ Isanti County (varying schedule by route)
    - Multiple within- or cross-county routes centered on Cambridge

- Cambridge DAR

➔ Stark Transport (Medical services)

- Evening service 8 PM - 2 AM for MN Safe Rides -
- Chisago, Isanti, and surrounding counties with taxi and Non-Emergency Medical Transportation (NEMT) rides

➔ SchuTran (Medical services)

- Weekdays and some limited weekend times
- Medical rides by appointment

➔ Jefferson Lines (Intercity route)

- Daily North to South connection from Twin Cities to Duluth along I-35
- Passes through Pine City and Hinckley

1.2 TRANSIT TYPES AND ROUTES

The three general transportation providers or *transit agencies* operate the following types of transit services or *routes* in the five counties:

1. **Demand-Responsive Transit (DRT)**: Encompassing Dial-a-Ride (DAR), this is a reservation-based curb-to-curb transit service. Riders can request trips within a defined service area and time window. When possible, agencies consolidate multiple requests to optimize vehicle dispatching—an approach that typically requires advance booking (e.g., a day in advance or at least one hour prior to the ride). The DRT routes serviced within the ECRDC area are as follows:
    - Pine City DAR (city-wide service)
    - Cambridge DAR (city-wide service with some restrictions)
    - North Branch DAR (city-wide service with some restrictions)
    - Timber Trails DAR (covering 16 cities/towns in Kanabec County)
    - Mille Lacs County DAR (covering 13 cities/towns and Zimmerman)
2. **Route Deviation**: These operate on set corridors and schedules like conventional buses but allow off-route pickups or drop-offs (i.e., deviation) by request. The routes in operation, all by Arrowhead Transit, are:
    - *Pine City to Duluth* and *Pine City to North Branch* routes (2 routes)

- 7 regular routes departing from the City of Sandstone
- Cambridge-centered *Braham-Rush Point Commuter*, *Braham Express*, *Pine Brook-Grandy Commuter*, *Long Lake Commuter,* and the Saturday route (5 routes total)
- North Branch-centered *South Chisago County Comm*, *HWY 61 Blue Line*, *Tri-City Commuter*, and the Saturday route (4 routes total)

3. **Hybrid**: These combine the route deviation service with on-demand flexibility. Vehicles follow a deviation-allowed designated corridor while accommodating pick-up and drop-off requests at any time during service hours, subject to vehicle and driver availability. Arrowhead's *Chisago Lake's Commuter* route is the only example of this type of service within the study area.

Unlike conventional urban bus services that operate on a stop-to-stop basis, the three transit service types discussed here have specific service areas. DRT services provide curb-to-curb trips within a predefined service area. On the other hand, Route Deviation/Hybrid services allow for minor deviations from the designated route to facilitate boarding and alighting. All services require reservations, and boarding/ alighting locations must be requested and coordinated in advance.

A visual summary of the service areas for all 24 routes is provided in **Figure 1**.

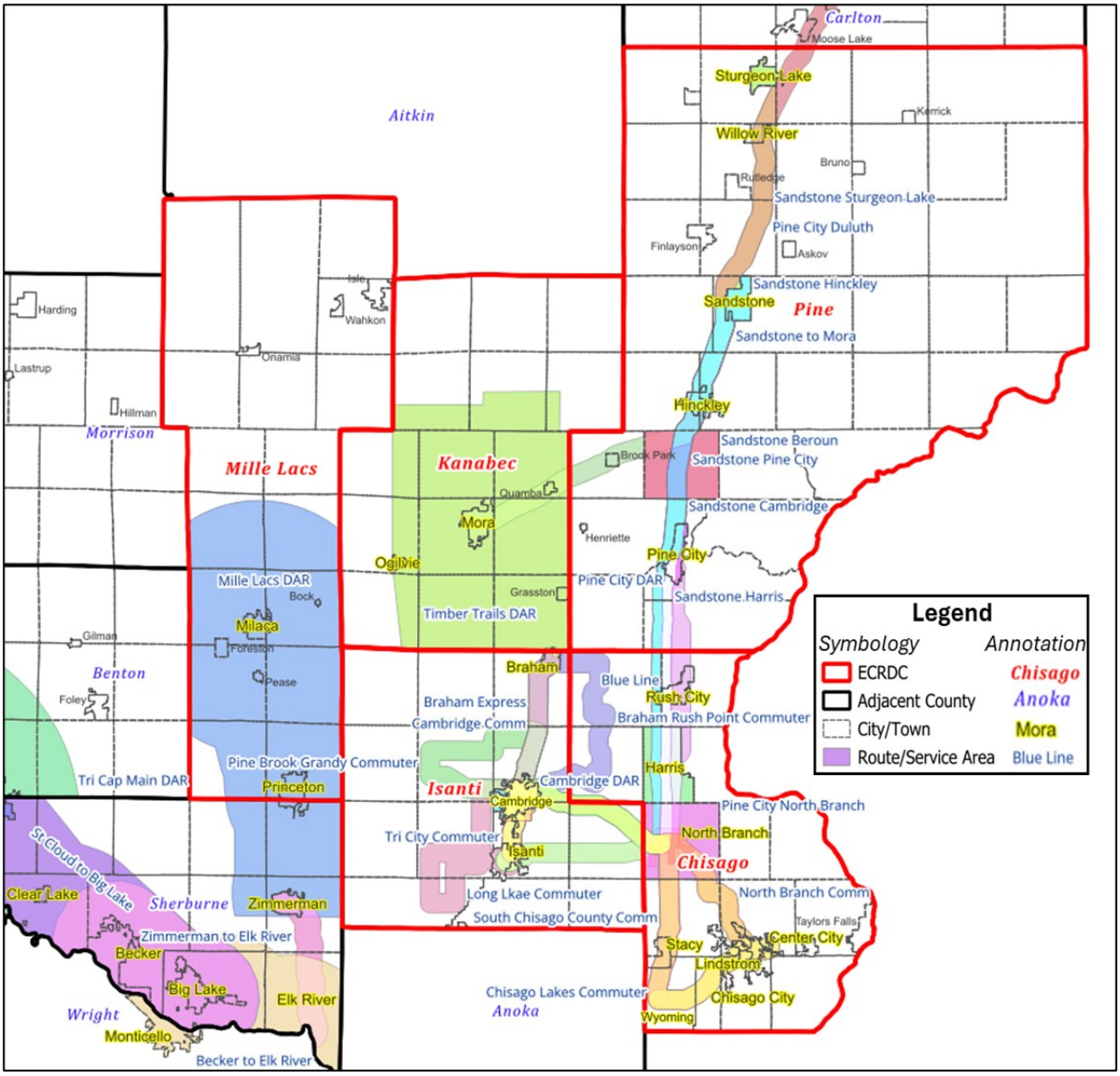


Figure 1 The three transit agencies' routes/service areas (including adjacent counties)

As noted, the above classification and **Figure 1** do not include medical transportation (Stark Transport, SchuTran) and Jefferson Lines' long-distance intercity routes.

CHAPTER 2: FOCUS GROUP RESEARCH (QUALITATIVE METHODS)

2.1 DESCRIPTION OF THE FOCUS GROUP RESEARCH PROCESS

2.1.1 Purpose

In collaboration with regional partners, East Central Regional Development Commission (ECRDC) and Lighthouse Child & Family Services (Lighthouse), the University of Minnesota (UMN) qualitative research team (Michael Darger, Frank Douma and Ted Jessup) investigated transportation needs for people in the region. The main goals of this qualitative assessment were to:

1. Articulate the key transit needs in the East Central Minnesota area (in particular, Mille Lacs and Kanabec Counties), noting in particular those transit needs related to youth transportation and non-emergency medical trips in particular.
2. Note key legal and policy constraints currently operating to create identified gaps.
3. Note areas where data is still needed to develop a potential service plan.
4. Provide suggestions for addressing some of these needs, including identifying potential funding sources, if appropriate.

2.1.2 Recruitment and Logistics

The six group meetings were held at public or nonprofit facilities in Milaca, Onamia and Mora. Food and beverages were provided. The meetings were facilitated by Michael Darger and observed and recorded by Frank Douma or Ted Jessup. Each participant in the rider/would-be rider groups (1, 2, and 3) were given $75 Visa gift cards for their time. Zoom recordings were made for each focus group and transcripts shared with the qualitative research team.

2.1.3 Procedures

Data was collected through six focus groups in October, November and December 2024. These were facilitated and recorded by the research team in Milaca and Onamia (Mille Lacs County) and Mora (Kanabec County). The insights and needs of transit riders and their advocates/families as well as various other stakeholders were gathered. The following focus group target audiences were convened. The groups were facilitated using the methods promulgated by Richard Krueger Ph.D., (*Focus Groups – A Practical Guide for Applied Research* 5th Edition, 2015).

(1) **People who cannot drive**. Non-emergency medical and other transit-dependent riders / stakeholders / people who arrange rides. This includes Lighthouse families (Mille Lacs), veterans and others. Focus Group 1 was held October 21, 2024 in Milaca with 7 participants.

(2) and (3) **Adult riders, or would-be riders. from Kanabec and Mille Lacs counties** (one session in each county). We think of these participants as those who choose or need transit for any kind of trip (including shopping, pleasure, commuting, etc.). Focus Group 3 was held in Mora on November 13, 2024 with 10 participants. Almost all were senior citizens. Focus Group 2 was held in Onamia on December 17, 2024 with 4 participants, including parents with young children at home.

(4) and (5) **Two groups of "mixed stakeholders," which we could also define as "non-transit-provider partners."** That is, people on this list (https://ecrdc.org/ecrtcc-partners/) who are not transit providers. Focus Group 5 was held in Mora on October 31, 2024 with 6 participants, representing agencies, employers, and nonprofit organizations who need their clients to get transportation. Focus Group 4 was held in Milaca on November 4, 2024. Several Mille Lacs County professionals and two others attended (7 participants).

Group (6) gathered the **transit providers** themselves. Focus Group 6 was held on November 21, 2024 in Mora with about six participants.

2.2 FOCUS GROUP FINDINGS

The comprehensive focus group research conducted in East Central Minnesota provides valuable insights into both the strengths and limitations of current transportation services in Mille Lacs and Kanabec Counties. Participants articulated a clear desire for expanded service availability, improved access to essential destinations, and innovative approaches to volunteer recruitment and operational efficiency. The development of multi-provider transit hubs and strategically located pick-up and drop-off locations emerged as promising strategies to enhance service coordination.

2.2.1 Effective Service Models

Focus group participants identified some transportation services that function effectively within their communities, mostly focusing on North-South routes and volunteer driver programs. Common destinations successfully served by current providers include small medical facilities, grocery stores, and local businesses, though service availability varies greatly by provider. Riders living within the city limits of Milaca consistently reported satisfactory reliability for North-South grocery trips between Milaca and Princeton.

With regard to specialized services, Timber Trails has developed effective protocols for accommodating school-aged children, including procedures to ensure safe transfers for young riders. Volunteer driver programs provide crucial support for medical transportation needs, offering flexible solutions for otherwise underserved areas.

SchuTran, in particular, received consistent positive feedback from participants regarding their medical transportation services. Participants highlighted SchuTran as a medical transportation provider with a superior performance record compared to alternatives.

While SchuTran received consistently positive feedback from riders eligible for medical assistance programs, participants who narrowly exceeded medical assistance eligibility thresholds highlighted affordability barriers. One such participant reported being quoted $300 per trip for transportation from Ogilvie to St. Cloud for medical services.

- *“They waited until I got inside my appointment, every time. That’s the kind of care people notice.”*
- *“She remembered my name, asked how my kids were doing.”*

2.2.2 Medical vs. Non-Medical Trips

Focus group participants noted that service is better for medical trips than trips for other purposes. Medical trips had more flexible services and geographical ranges, expanded time frames and subsidized costs. While an argument exists that medical trips are more important, and should receive priority over other trips, users do not find this to be a useful distinction. Participants noted that they also struggled with food security, but medical ride regulations do not allow stops at grocery stores as part of their services. To these people, it makes more sense for medical rides to allow for additional stops on the same trip, or that service areas for non-medical rides match that of medical rides. Participants did not understand why they were not able to stop a grocery stores that were located within medical ride service areas, but not areas served by other transit services.

- *“Sometimes the driver will stop at the store after a medical ride, but only if they’ve got nothing after you. That’s just them being kind.”*
- *“Some of us plan our appointments just so we can get into town and pick up food.”*

2.2.3 Service Limitations and Challenges

Despite the existence of certain effective service models, participants who require transportation outside of business hours or designated geographic regions expressed frustration with the limitations of the current system. With the exception of Stark Transport’s evening services (with a notably limited geographic range), most providers offer no evening, weekend, or late-night transportation options. Additionally, providers frequently operate at maximum capacity during peak hours, resulting in service denials.

- *"We're always full between 2 and 4. Can't squeeze in one more."*
- *"Beginning and end of day are impossible to get rides. Those are all locked in for workers."*
- *“If you work past 5, you’re on your own. And forget weekends.”*
- *“You can’t get a ride in the evening or weekend. So if your car’s down, that’s it. You’re stuck.”*

- There is a complete absence of transportation connections to major urban centers including St. Cloud, Duluth, and the Minneapolis-St. Paul metropolitan area, presenting barriers to accessing specialized medical care, social occasions, and travel hubs.

- *"You can't even get to a big hospital without borrowing someone's car."*

While participants noted that north-south services between Milaca and Princeton and Mora and Cambridge were well-used, those that lived just outside of city limit service areas felt arbitrarily excluded. Further, the lack of east-west service between Milaca and St. Cloud, and Mora and Pine City and Hinkley reduced the utility of existing services. Finally, some areas, such as northern Mille Lacs County had no service at all, and, overall, the transportation system suffers from a general inability to facilitate transfers between services for inter-city connections due to incompatible fare structures and technological systems, hindering mobility throughout the region.

- *"I'm a five-minute walk from town and I can't get picked up because of the line."*

- *"If you could just get to Pine [City], you'd be golden - you've got Jefferson, you've got the cities."*

- *"If you're in Onamia, you're out of luck. There's no bus, no nothing."*

- *"We need a bus bad. Just any bus - even once or twice a month - just to get groceries even."*

Operational obstacles include critical volunteer driver shortages resulting from inadequate IRS mileage reimbursement policies and burdensome 1099 reporting requirements. Although focus groups indicated somewhat better volunteer availability in the Milaca area compared to the Mora area, the shortage of drivers remains a pervasive challenge throughout the region.

- *"They're losing money doing this."*

- *"By the time they pay for maintenance and gas, they're probably in the hole."*

Aging vehicle fleets and insufficient funding for fleet replacement and maintenance create additional constraints for providers such as Timber Trails and Tri-CAP. Furthermore, inadequate communication and outreach about available transportation options prevent potential riders from utilizing existing services.

- *"We hear about buses coming out this way, but we've never actually seen one."*

- *"I've never seen the TriCap bus. I was told it comes through, but nobody's actually seen it."*

2.2.4 Priority Destinations for Service Expansion

The focus groups identified several critical destinations where expanded transportation options would improve accessibility and quality of life for residents. Urban medical centers in St. Cloud, Duluth, and the Minneapolis-St. Paul metropolitan area were consistently identified as high-priority destinations due to their specialized healthcare services. Grocery retailers in Princeton and Cambridge offer more affordable

food options compared to stores in Milaca or Mora. For residents of Onamia or Isle, local grocery options are prohibitively expensive, and there are currently no transportation options available to access more affordable alternatives.

Participants frequently emphasized the need for increased transportation service to religious institutions, educational facilities, and community centers to support social, recreational, and daily needs. The focus groups revealed that some of these services existed in the past, like rides to Sunday church service, but were discontinued at some point due to cost.

- *"I just wish I could get dropped off at the state park for the day or take the kids to a playground. But there's no way to get there."*

The development of stronger connections to inter-city transportation networks such as Metro Transit and Jefferson Lines would facilitate greater regional mobility and enable residents to maintain connections with family members in other parts of the state.

Educational institutions including Pine Technical and Community College were identified by multiple participants as destinations that would expand opportunities for current and prospective students lacking reliable personal transportation.

2.2.5 Transit Provider Perspectives

Transportation providers emphasized the need for legislative action and increased funding to improve inter-agency collaboration, standardize fare structures, and enhance software compatibility across jurisdictions. Volunteer drivers were universally acknowledged as critical to rural transportation service provision, but current policies and evolving social norms impede recruitment efforts and driver retention.

Legislative reform was identified as necessary to integrate technological systems, fare structures, and route planning across county and service area boundaries.

- *"They go way out, pick up one person, then deadhead home. That's gas and time wasted."*
- *"The software doesn't talk to each other. We have to do everything by hand between counties."*

Some providers strongly emphasized that current reimbursement caps hinder volunteer retention, though this perspective was not universally shared among all providers. Some providers noted that their current drivers expressed less concern about the insufficient reimbursement rates than about other factors affecting their service.

- *"We can't attract drivers when mileage reimbursement is capped at 14 cents per mile. They're losing money doing this."*

The aging demographic profile of rural communities and diminishing social cohesion were also identified as barriers to recruiting new volunteers.

2.2.6 Volunteer Driver Program Assessment

Volunteer drivers perform a vital function within the rural transportation ecosystem, particularly for individualized and flexible service needs. Most riders expressed appreciation for the flexibility and dedication demonstrated by experienced volunteers, particularly for medical transportation services.

- *“I was pregnant and hadn’t eaten all day. The volunteer driver stopped to get me a pizza and a soda after my appointment. You don’t get that kind of kindness often.”*
- *“They waited until I got inside my appointment, every time.”*

However, some participants in the rider focus groups reported experiencing uncomfortable or unprofessional interactions with volunteer drivers. These participants expressed uncertainty regarding procedures for reporting concerns or establishing accountability. Some riders also reported experiences that compromised their comfort and safety, concerning both driver conduct and vehicle condition. Poor experiences ranged from uncomfortable political conversations to unsafe driving or interior conditions. These experiences make up a small percentage of focus group conversations, but highlight the necessity of improving both training and reporting standards for volunteer driver programs in the future.

- *“We had a guy who just didn’t show. I missed my doctor’s appointment because of it.”*
- *“He yelled at me for being late, but he showed up early.”*
- *"One picked me up with a gas can full of fuel in the back seat... One had his trunk full of smelly beer cans for recycling."*

Additionally, substantial challenges with recruitment and retention of volunteer drivers persist. These challenges stem from multiple factors, including insufficient IRS mileage reimbursement rates, an aging volunteer population, and burdensome administrative requirements. Several participant discussions reflected broader societal trends, including declining volunteerism and increased wariness of interactions with strangers, as contributing factors to the recruitment difficulties.

The variability in driver performance creates challenges for the transit providers. Persistent difficulties with recruitment and retention create disincentives for volunteer programs to implement disciplinary measures for underperforming drivers, as programs fear losing essential service capacity for vulnerable groups.

2.2.7 Proposed Solutions and Innovations

Focus group participants and transportation providers identified several innovative approaches to address the region's transportation challenges:

Development of mobility hubs, implementation of vehicle-sharing models, and establishment of subsidized ride-sharing programs were proposed as potential solutions to address critical service gaps.

- *"If we had a central location for pickups, even if the bus only came a few times a month, people would use it. We just don't have any options right now."*

Creation of shared pick-up hubs across county boundaries could reduce "deadheading" (unloaded miles), improving operational efficiency and reducing costs. Several participants discussed the potential benefits of developing direct ride-matching services based on rider input and destination requests.

- *"We need something like a website where you put in what you need, and someone who can help see it and can make it happen."*

Enhanced community outreach through educational institutions, healthcare facilities, and local businesses could effectively increase public awareness regarding available transportation options. Participants consistently referenced the digital divide affecting rural communities, particularly regarding age demographics and internet accessibility, emphasizing that transportation providers must diversify their communication strategies beyond digital platforms.

- *"Not everyone has Wi-Fi or a smartphone. Flyers in gas stations or churches go farther here."*
- *"Put the info on the Dollar General window or the school bulletin board."*

CHAPTER 3: TRANSIT GAP (QUANTITATIVE) ANALYSES

3.1 TRANSIT SERVICE AVAILABILITY

To assess transit coverage and frequency (i.e., availability), we estimated the practical number of typical weekday trips that can be accommodated from an arbitrary location within each route's service area. This metric serves as a proxy for "ride availability" or "effective frequency" and is retrieved from the following process for each service type:

- **DRT**: To determine transit service availability for each DRT route, we posed a hypothetical question to the operating agency, following a relevant explanation. The answer, combined with the service hour span and agency-reported in-city/intercity trip proportion, allowed us to calculate the route-level maximum number of vehicles that could be dispatched to a specific point per day. The question used was:
  "*Based on your experience, for two typical passenger requests with similar origin-destination pairs for [route name], what's the smallest time difference between their requested departure times that would make you send out two separate vehicles instead of trying to combine them into one shared ride?*"

- **Route Deviation**: Daily trip counts were directly retrieved from the published schedules to be used as the availability.

- **Hybrid**: *Chisago Lake's Commuter*, the sole route in this category, began operations on June 2, 2025. Due to insufficient historical data for analysis, we estimated that the service could accommodate approximately double the published "Approximate Times" of a minimum of four times' loop daily, resulting in eight services used for the availability.

For each route, the service area was digitized as a polygon on a map. We then assigned the effective daily frequency or practical number of transit ride availability (trips per day) as a property of each polygon. By overlapping these numbers, we determined the transit service availability for every location within the five-county study area. For instance, if a specific point is served exclusively by two routes with daily frequencies of four and eight, respectively, the transit service availability for that point is 12 times per day.

Figure 2 illustrates the Transit Service Availability across all points in the five-county study area, incorporating the overlapped effective frequencies of all 24 routes. The map reveals significant variation in transit ride availability:

- Rural areas often have limited daily or only monthly service.

- Regional centers, however, enjoy practical transit access with over 40 daily trips.

The figure also indicates transit services in Mille Lacs and Kanabec Counties are straightforward, offering only DAR services primarily in cities such as Milaca, Princeton, and Mora. In contrast, the other three

counties, where transit is managed by Arrowhead, feature a more complex system with multiple overlapping routes with higher transfer possibilities.

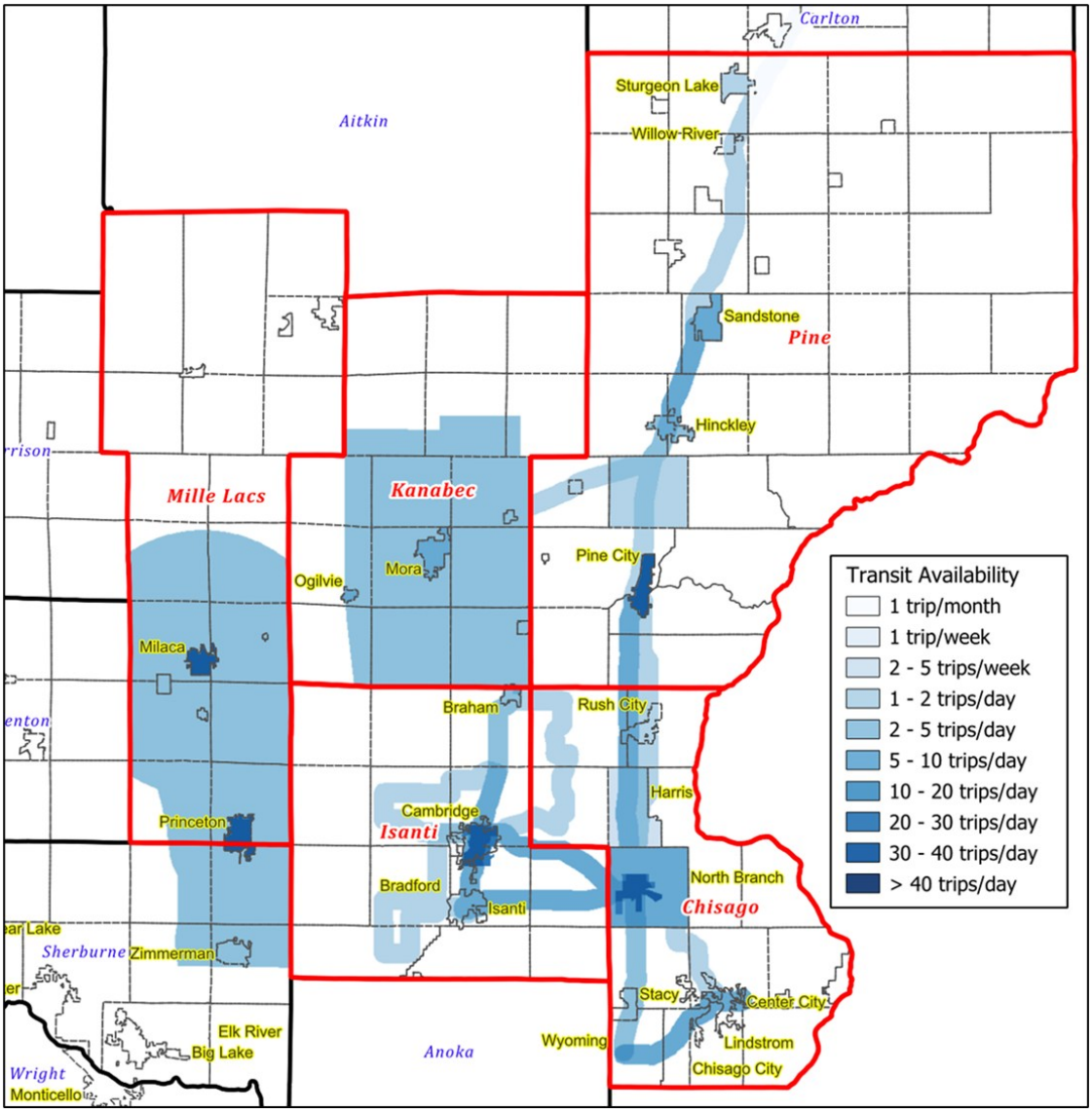


Figure 2 Transit Service Availability

On the other hand, one of the findings from the focus groups in **Section 2.2** was that the current service hours lack flexibility, hindering access to transit during early mornings, evenings, and weekends. To illustrate this, **Figure 3** compares transit availability across four time windows: (a) all routes operating combined, (b) weekday early morning (before 7 AM), (c) weekday evening (after 5 PM), and (d) Saturday. The figure confirms that in such off-peak hours, residents may have challenges in taking transit compared to the hours when most transit services are available (roughly 9 AM – 3 PM on weekdays).

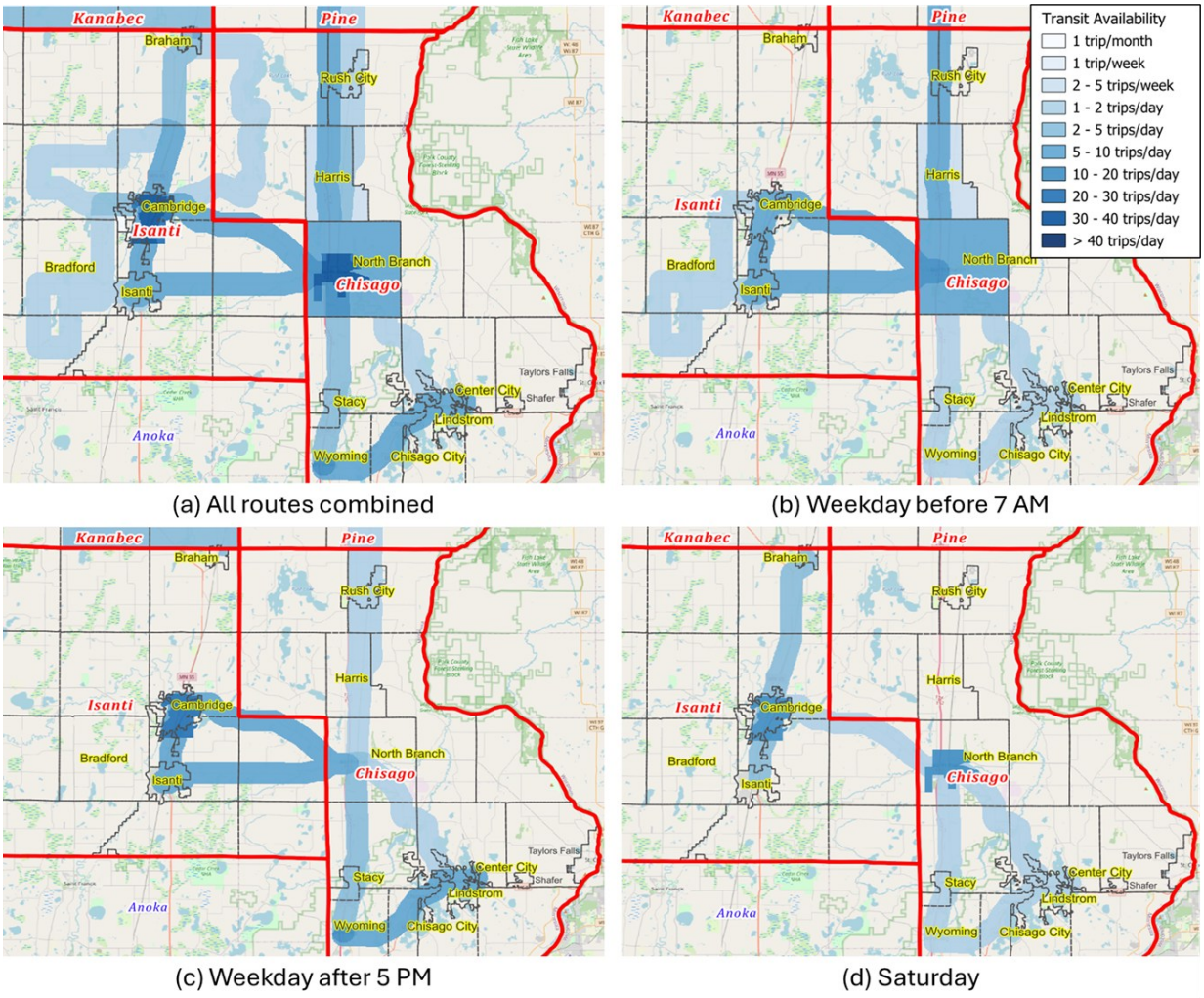


Figure 3 Transit Service Availability comparison by time of day and day of week

3.2 TRANSIT COVERAGE

A county seat typically represents the most populous or accessible city within a county, generating significant travel demands for government and court activities, and often serving as a hub for commercial and public services. Therefore, assessing the transit coverage of county subdivisions is crucial for understanding general service accessibility for county residents.

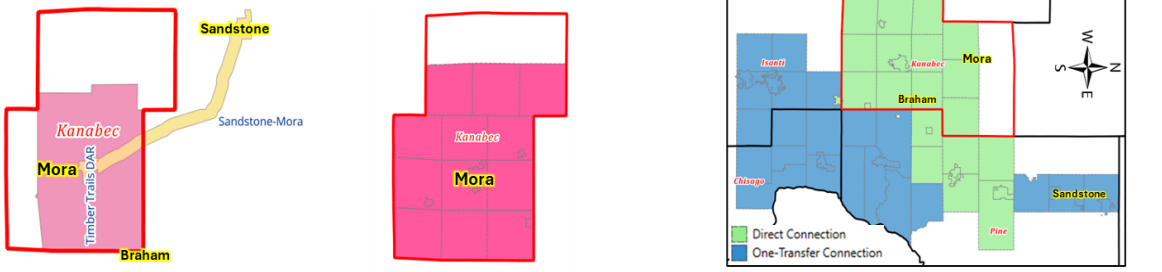
In our five-county study area, the county seats for Mille Lacs (Milaca), Kanabec (Mora), Isanti (Cambridge), and Pine (Pine City) are also their most populous cities. However, in Chisago County, while Center City is the county seat (part of the Chisago Lake Area, which includes Chisago City and Lindstrom), North Branch is the most populous city.

Consequently, we evaluated transit coverage from these five county seats, plus North Branch, with methods exemplified for Kanabec County in **Figure 4**. Our assessment involved three key measurements, and the results are summarized in **Table 1**:

1. **Within-county Coverage**: We determined the number and proportion of subdivisions within each county covered by transit at least once on a weekday (counted if any part of the subdivision was within a transit route's service area).

2. **Regional Coverage**: To gauge broader connectivity, we counted the number of subdivisions accessible via direct or one-transfer transit connections, without any location filter.

3. **Intercity Service Connectivity**: We measured the number of transit transfers required to connect to intercity services serving major state cities: St. Cloud, Duluth, and the Twin Cities.



1. Two transit routes serve from the county government at Mora

2. The two routes touch 16 out of 19 (84%) subdivisions in Kanabec Co.

3. Including out-of-county areas, they touch 25 (direct) and 47 (when transferred) subdivisions

Figure 4 Transit coverage analysis method (exemplified with Kanabec County)

Table 1 Transit coverage analysis from the five county seats and the City of North Branch

County (City)	Within-County Coverage		Regional Coverage (Counts)		Intercity Connectivity (Twin Cities, St. Cloud, and Duluth)	
	Count	Prop-ortion	Direct	One transfer	Closest intercity stop	How to access the stop (transit routes to use)
Mille Lacs (Milaca[*†])	13/25	52%	19	20	Elk River (North Star[1])	*(1 transfer) Mille Lacs DAR-> Zimmerman-Elk River* Route
Kanabec (Mora[*†])	16/19	84%	25	47	Hinckley (Jefferson Lines[2])	*(Direct connection) Sandstone-Mora* Route
Isanti (Cambridge[*†])	10/17	59%	13	49	North Branch (Jefferson Lines[2])	*(Direct connection) Tri-City Commuter* Route

Chisago (Center City*)	8/19	42%	8	25	North Branch (Jefferson Lines[2])	*(Direct connection)* *South Chisago Comm.* Route
Chisago (North Branch†)	15/19	79%	25	40	North Branch (Jefferson Lines[2])	*(Direct connection)* *North Branch DAR*
Pine (Pine City*†)	12/47	26%	22	37	Pine City (Jefferson Lines[2])	*(Direct connection)* *Pine City DAR*

**County Seat; †Most populous city in the county*

[1]Metro Transit's North Star Commuter (Rail/Bus) provides intercity connections to Minneapolis and St. Cloud

[2]Jefferson Lines (I-35 Route) provides intercity connections to Minneapolis/St. Paul and Duluth

Kanabec County demonstrates the most comprehensive transit connectivity from its county seat to internal subdivisions, with 16 of 19 directly accessible via *Timber Trails DAR* route. Conversely, Pine County, with the largest number of subdivisions and the largest land area, exhibits the lowest proportion of accessible areas due to the concentration of transit services along I-35.

Regional coverage, assessed by the total number of county subdivisions reachable regardless of which county they belong to, highlights inter-county routes' importance, such as the *Mille Lacs DAR* (extending to northeastern Sherburne County) and numerous connections between Cambridge-North Branch (Chisago/Isanti Counties) and I-35 routes across the Pine-Chisago county border.

Notably, allowing a single transfer significantly boosts accessible subdivisions in Kanabec County, facilitated by a small overlap in the City of Braham between Timber Trails DAR and some Isanti County routes. Additionally, North Branch, Cambridge, and Pine City serve as hubs where multiple routes intersect, leading to a significant increase in one-transfer coverage due to transfer opportunities within these cities or their connected areas.

Finally, five of the six cities offer direct access to intercity bus services via Jefferson Lines, some utilizing DRT services within the city. However, Milaca, Mille Lacs County's seat, necessitates one transfer at Zimmerman to Sherburne County's transit service (operated by the same Tri-Cap agency) to reach the Elk River station ultimately.

3.3 TRANSIT DIRECTIONALITY

The qualitative focus group interviews in **Section 2.2** highlighted a significant finding: residents perceive an imbalance in east-west versus north-south transit connections. This directional disparity is further explored in this section, utilizing the regional road network, transit service areas (**Section 1.2**), and daily transit service availability (**Section 3.1**).

Figure 5 illustrates the primary road network supporting the 22 weekday transit routes within the ECRDC area. These roads include Interstate Freeways, U.S. and Minnesota Highways, as well as select county and municipal roads utilized for route deviation and hybrid transit services. It suggests a strong north-south orientation in the regional transit network compared to east-west connectivity, as well as a noticeable service gap in the area to the east of the Mille Lacs County border.

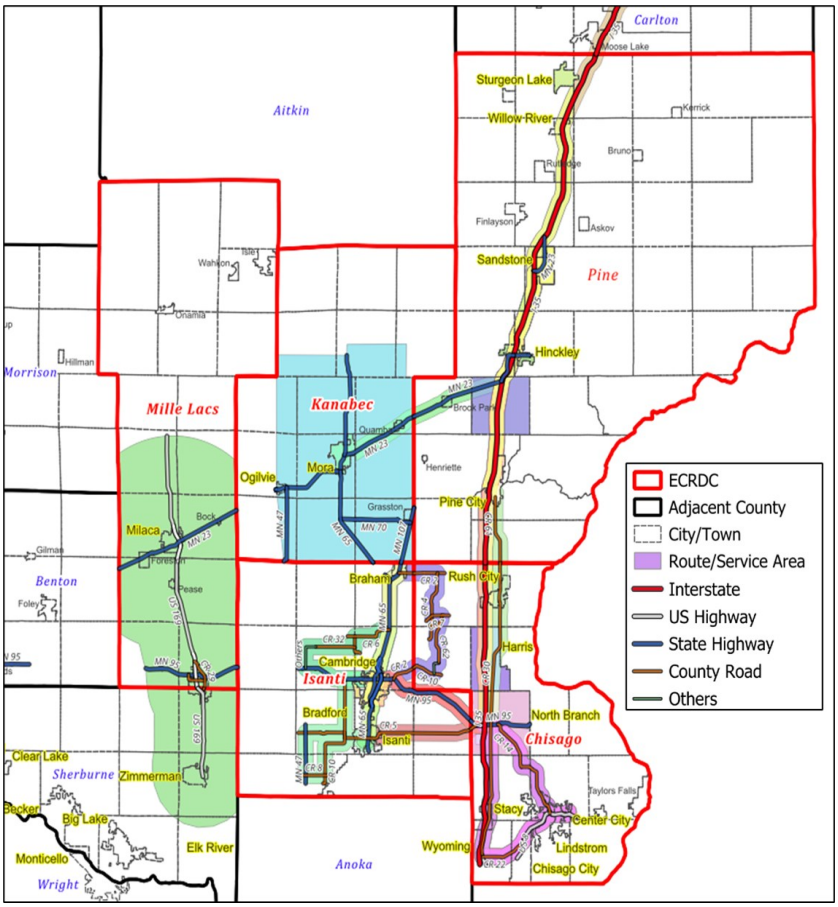


Figure 5 Major roads on which the 22 weekday transit routes operate

To quantify this, we analyzed the practical daily absolute directional movement along major roads for each transit route, as illustrated in **Figure 6**. First, we identified portions of highways that overlap with each transit service area. We then split these overlaps into linear segments and decomposed them into horizontal (s_x) and vertical (s_y) components.

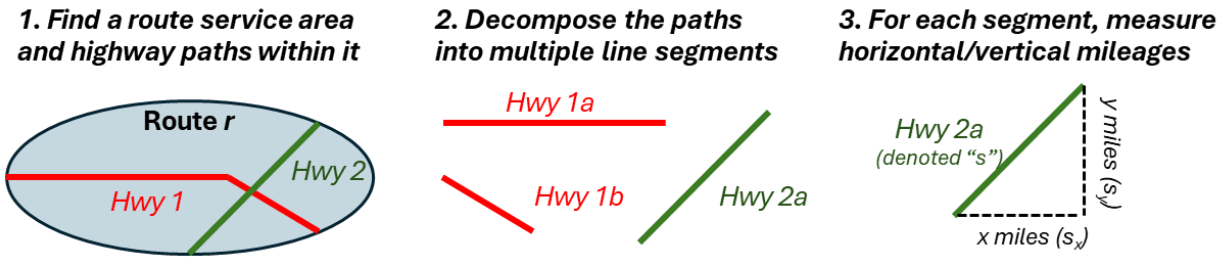


Figure 6 Method to retrieve horizontal and vertical components for each transit route

Next, we multiplied each s_x and s_y component by the Transit Service Availability (n_r: **Section 3.1**) of its respective transit route r. This gave us the practical daily horizontal movement (h_r) and vertical movement (v_r) at the route level. A detailed derivation is explained in **Appendix A**.

Table 2 summarizes, for each route, n_r, h_r, and v_r values, where the last column presenting v_r/h_r, signifies how much the vertical movement is dominant for the route compared to its horizontal movement. Numbers are summarized at both a global and county level for Isanti, Chisago, and Pine Counties, all of which operate multiple routes. The global sum, excluding DRT route numbers, is also included as the final row. This exclusion is due to the multiple assumptions underlying the retrieval and calculation of DRT routes' transit service availability, and their actual operations are highly subject to individual requests..

The result clearly shows the dominance of north-south transit movement in terms of the weighted mileage, nearly doubling (at 1.9) that of east-west travel for all county-level summaries, and the global sum with DRT services is removed. In contrast, Chisago County's *Tri-City Commuter* route stands out as the only route with a meaningfully longer sum of the horizontal components.

However, it is worth noting that this analysis has two primary limitations. First, the practical number of trips for DRT services is based on the question, assuming the most typical operations. In reality, service frequency and expected waiting times can vary significantly within the same DRT route's service area depending on location, staffing, time of day, and real-time demand. Second, all routes in the study area allow for deviations, meaning local roads are frequently used. The lengths of these local road segments are not accounted for in the current h_r and v_r calculations. In addition, the actual movement of vehicles can be concentrated on specific road segments, whereas the numbers derived in the table assume a uniform distribution of the movement along those major roads within each route's service area.

Table 2 Horizontal and vertical transit movement comparison

Primary County	Route	Service Type	n_r (trips/day)	h_r (mi)	v_r (mi)	v_r/h_r
Chisago	*North Branch DAR*	DRT	22	76	98	1.29
	Chisago Lakes Commuter	Hybrid	8	95	99	1.04
	South Chisago Co. Commuter	Route Deviation	2	46	84	1.82
	Highway 61 Blue Line	Route Deviation	2	22	128	5.96
	Tri-City Commuter	Route Deviation	6	180	139	0.77
Chisago County Total				419	548	1.31
Isanti	*Cambridge DAR*	DRT	22	132	204	1.55
	Braham Express	Route Deviation	3	29	58	2.02
	Braham-Rush Point Commuter	Route Deviation	2	50	69	1.38
	Pine Brook-Grandy Commuter	Route Deviation	2	54	54	0.99
	Long Lake Commuter	Route Deviation	2	45	60	1.32
Isanti County Total				311	445	1.43
Pine	*Pine City DAR*	DRT	24	16	102	6.22
	Pine City - Duluth	Route Deviation	1/month	7	9	1.36
	Pine City - North Branch	Route Deviation	7	99	396	4.02
	Sandstone - Beroun	Route Deviation	2	28	73	2.56
	Sandstone - Cambridge	Route Deviation	1/month	2	5	2.93
	Sandstone - Harris	Route Deviation	1	18	84	4.77
	Sandstone - Hinckley	Route Deviation	3	25	61	2.44
	Sandstone - Mora	Route Deviation	1.5	42	57	1.37
	Sandstone - Pine City	Route Deviation	1/week	3	10	3.50
	Sandstone - Sturgeon Lake	Route Deviation	1.5	20	63	3.22
Pine County Total				258	859	3.33
Kanabec	*Timber Trails DAR*	DRT	4.8, 2.93*	339	459	1.35
Mille Lacs	*Mille Lacs DAR*	DRT	32.3, 2.4*	91	145	1.59
Grand Total				1,418	2,456	1.73
Grand Total (excluding DRT services)				763	1,448	1.90

* *n_r values for the route are retrieved separately for in-city (former number) and cross-city (latter) trips*

3.4 TRANSIT GAP

To estimate the relative theoretical demand for trips between each city/township (county subdivision) pair within the five-county study area, we employ the well-established trip distribution model (Ortúzar & Willumsen, 2011). In its most basic form, this model posits that the number of trips originating from subdivision A and destined for subdivision B is directly proportional to the populations of both subdivisions, and inversely proportional to the travel time between them, raised to a constant parameter. We used this concept to compute the **travel demand index** between points A and B.

On the other hand, we can evaluate the expected **impedance** of using transit between each county subdivision pair. This is done by considering the overlap of transit route service areas, which accounts for potential transfers. We designed this impedance to measure the number of transfers required for a transit-only journey between subdivisions A and B. If a direct (no-transfer) transit route already exists, we adjusted the impedance to a lower value using the daily transit service availability (**Section 3.1**), reflecting excellent current connectivity.

Both the derivation of the travel demand index and impedance are explained in **Appendix B**.

Figure 7 shows the calculated demand index (in upper triangle cells) and impedance (in lower triangle cells) values for each trip pair of the top 15 populous cities in the five-county area. Here, the symmetry holds: the value from A to B is equal to the value from B to A. Therefore, the information shown is exhaustive for the 15 cities' all possible pairwise combinations.

Demand (Upper) and Impedance (Lower)	Pine				Chisago					Isanti			Kanabec	Mille Lacs	
	Sandstone	Hinckley	Pine City	Rush City	North Branch	Stacy	Wyoming	Chisago City	Lindstrom -Ctr. City	Isanti	Cambridge	Braham	Mora	Milaca	Princeton
Sandstone		4.26	3.83	3.08	4.28	1.43	3.38	2.60	2.44	2.90	3.58	1.73	3.47	2.12	2.27
Hinckley	0.11		4.09	3.01	4.04	1.12	3.04	2.22	2.07	2.52	3.22	1.54	3.47	1.81	1.87
Pine City	0.43	0.43		5.56	6.04	2.94	4.78	3.86	3.72	4.16	4.93	3.66	3.92	2.52	2.95
Rush City	0.49	0.49	0.09		6.87	3.55	5.33	4.31	4.17	4.41	5.27	3.34	3.39	2.34	3.17
North Branch	0.95	0.95	0.10	0.10		6.88	8.37	7.33	7.24	7.08	8.15	4.56	4.93	4.16	5.54
Stacy	2.00	2.00	0.33	0.33	0.20		7.49	5.68	5.31	3.96	4.88	1.54	2.05	1.34	2.62
Wyoming	2.00	2.00	0.33	0.33	0.20	0.20		7.64	6.94	5.82	6.69	3.44	3.99	3.31	4.55
Chisago City	2.00	2.00	1.00	1.00	0.33	0.33	0.08		9.36	4.94	5.75	2.61	3.23	2.58	3.77
Lindstrom -Ctr. City	2.00	2.00	1.00	1.00	0.33	0.33	0.08	0.08		4.78	5.61	2.45	3.06	2.41	3.6
Isanti	2.00	2.00	1.00	1.00	0.14	1.00	1.00	1.00	1.00		8.75	4.66	4.77	3.92	5.49
Cambridge	1.95	1.95	1.00	1.00	0.14	1.00	1.00	1.00	1.00	0.09		5.74	5.61	4.76	6.53
Braham	1.00	1.00	2.00	2.00	1.00	2.00	2.00	2.00	2.00	1.00	0.13		3.95	2.33	2.95
Mora	0.40	0.40	1.00	1.00	2.00	3.00	3.00	3.00	3.00	2.00	1.00	0.06		4.49	4.09
Milaca	5.00	5.00	5.00	5.00	5.00	5.00	5.00	5.00	5.00	5.00	5.00	5.00	5.00		5.45
Princeton	5.00	5.00	5.00	5.00	5.00	5.00	5.00	5.00	5.00	5.00	5.00	5.00	5.00	0.14	

**Note: The travel demand index (upper right triangle) values are color-coded, and the top 15 populous cities are grouped by the county they belong to, where the county seat cities are highlighted*

Figure 7 Trip demand index and current transit connectivity for the top 15 cities' pairs

To reiterate, the upper triangle of the matrix represents travel demand, while the lower triangle illustrates impedance. By multiplying these corresponding values pairwise, we can compute the **transit gap**. A higher gap value indicates high potential demand coupled with high current impedance. **Figure 8** displays a similar matrix: the lower-left triangle presents the calculated transit gap, and the upper-right triangle shows its rank (with rank 1 representing the highest gap and 105 the lowest).

Rank (Upper) and Transit Gap (Lower)	Pine				Chisago					Isanti			Kanabec	Mille Lacs	
	Sandstone	Hinckley	Pine City	Rush City	North Branch	Stacy	Wyoming	Chisago City	Lindstrom -Ctr. City	Isanti	Cambridge	Braham	Mora	Milaca	Princeton
Sandstone		104	82	86	64	72	34	48	54	42	32	80	89	24	23
Hinckley	0.48		78	87	68	75	40	58	63	49	38	84	89	30	28
Pine City	1.67	1.78		103	101	94	83	67	69	62	51	31	66	18	14
Rush City	1.50	1.47	0.50		99	91	78	60	61	59	46	37	70	21	13
North Branch	4.08	3.85	0.60	0.68		90	82	73	74	93	92	57	25	**7**	**2**
Stacy	2.86	2.24	0.98	1.18	1.38		86	76	79	65	54	71	39	35	16
Wyoming	6.76	6.08	1.59	1.78	1.67	1.50		100	102	41	36	33	20	12	**5**
Chisago City	5.20	4.44	3.86	4.31	2.44	1.89	0.64		96	50	43	47	26	17	**10**
Lindstrom -Ctr. City	4.88	4.14	3.72	4.17	2.41	1.77	0.58	0.78		55	45	52	29	19	11
Isanti	5.80	5.04	4.16	4.41	1.01	3.96	5.82	4.94	4.78		97	56	27	**9**	**3**
Cambridge	6.99	6.29	4.93	5.27	1.16	4.88	6.69	5.75	5.61	0.76		98	45	**4**	**1**
Braham	1.73	1.54	7.32	6.68	4.56	3.08	6.88	5.22	4.90	4.66	0.72		105	22	15
Mora	1.39	1.39	3.92	3.39	9.86	6.15	11.97	9.69	9.18	9.54	5.61	0.25		**6**	**8**
Milaca	10.60	9.05	12.60	11.70	20.80	6.70	16.55	12.90	12.05	19.60	23.80	11.65	22.45		96
Princeton	11.35	9.35	14.75	15.85	27.70	13.10	22.75	18.85	18.00	27.45	32.65	14.75	20.45	0.78	

**Note: The transit gap's rank (upper right triangle) values are color-coded, and the top 15 populous cities are grouped by the county they belong to, where the county seat cities are highlighted*

Figure 8 Transit gap and transit gap rank for the top 15 cities' pairs

The rank values in the figure suggest that, generally, an expansion of the service area or an increase in the number of trips for high-ranking cells (darker cells) should be prioritized.

Milaca and Princeton, two cities in Mille Lacs County, are not connected to the transit systems of the other four counties, despite having a connection to Sherburne County's transit system. This lack of connectivity (high impedance) generally results in higher transit gap ranks, as shown in the last two columns. Therefore, **Table 3** was created to highlight the 10 highest gap values among the top 15 city pairs, followed by another 10 pairs that do not involve the two Mille Lacs County cities.

The table indicates that establishing a transit connection between Cambridge and Princeton is of paramount importance. This is followed by other instances involving Princeton and Milaca, notably including a Mora-Milaca connection, which is distinct from the North Branch-Cambridge-Princeton corridor along State Highway 95.

For the top 10 pairs not associated with the two Mille Lacs County cities, the gap ranks range from 20 to 36. Significant gaps include cross-county connections, primarily to Mora, and connections between cities

located along two different corridors: State Highway 65 (Braham, Cambridge) and I-35 (Pine City, Sandstone, Wyoming). Notably, the Wyoming-Cambridge pair, despite already requiring only one transfer, is included due to its high potential trip demand. Essentially, no origin-destination pairs with existing direct connections are included in the higher priority, emphasizing that expanding service areas and facilitating transfers are currently more critical than increasing service frequency.

Thus far, the transit gap has mainly been calculated for city pairs that already have a transit connection. However, some origin-destination pairs are where either end is outside the top 15 populous cities, yet they still possess a high travel demand index. **Table 4** summarizes 12 such pairs with the highest travel demand index. Most of the top pairs with a higher demand index are situated along US Highway 8 (Lindstrom-Center City-Shafer-Taylors Falls). Another pair, Ogilvie-Milaca (State Highway 23), which is a sub-segment of the Mora-Milaca pair (ranked fourth in **Table 3**), also appears in this list.

Table 3 Important transit gaps identified for the top 15 cities' pairs

Rank		City 1	City 2	Travel Demand Index	Impedance	Gap
Top 10	1	Cambridge	Princeton	6.53	5.00	32.7
	2	North Branch	Princeton	5.54	5.00	27.7
	3	Isanti	Princeton	5.49	5.00	27.5
	4	Cambridge	Milaca	4.76	5.00	23.8
	5	Wyoming	Princeton	4.55	5.00	22.8
	6	Mora	Milaca	4.49	5.00	22.5
	7	North Branch	Milaca	4.16	5.00	20.8
	8	Mora	Princeton	4.09	5.00	20.5
	9	Isanti	Milaca	3.92	5.00	19.6
	10	Chisago City	Princeton	3.77	5.00	18.9
Next 10, excluding pairs either with Milaca or Princeton	20	Wyoming	Mora	3.99	3.00	12.0
	25	North Branch	Mora	4.93	2.00	9.86
	26	Chisago City	Mora	3.23	3.00	9.69
	27	Isanti	Mora	4.77	2.00	9.54
	29	Lindstrom	Mora	3.06	3.00	9.18
	31	Pine City	Braham	3.66	2.00	7.32
	32	Sandstone	Cambridge	3.58	1.95	6.98
	33	Wyoming	Braham	3.44	2.00	6.88
	34	Sandstone	Wyoming	3.38	2.00	6.76
	36	Wyoming	Cambridge	6.69	1.00	6.69

Table 4 12 highest travel demand index pairs out of the top 15 populous cities

County 1	City 1	County 2	City 2	Travel Demand Index
Chisago	Lindstrom	Chisago	Shafer	6.2
Chisago	Chisago City	Chisago	Shafer	5.5
Chisago	Lindstrom	Chisago	Taylors Falls	5
Chisago	Chisago City	Chisago	Taylors Falls	4.7
Chisago	North Branch	Chisago	Shafer	4.6
Chisago	Shafer	Chisago	Wyoming	4.3
Chisago	North Branch	Chisago	Taylors Falls	4.2
Chisago	Shafer	Chisago	Taylors Falls	4
Chisago	Taylors Falls	Chisago	Wyoming	3.9
Chisago	Shafer	Isanti	Cambridge	3.2
Chisago	Taylors Falls	Isanti	Cambridge	3
Kanabec	Ogilvie	Mille Lacs	Milaca	2.5

*The transit gap is not used in this table as the impedance and gap are redundant in these cases, since no transit service, even with transfers, is currently available.

3.5 RECOMMENDATIONS TO ADDRESS THE IDENTIFIED TRANSIT GAPS

The quantitative transit gap analyses revealed transit availability in East Central Minnesota varies dramatically across space, time, and service type, with regional centers enjoying relatively frequent service while others face significant limitations—sometimes with service as infrequent as once per month.

By modeling theoretical trip demand using a gravity-based index and comparing it against current service availability and connectivity, the study identified severe transit gaps, particularly between city pairs like Cambridge–Princeton and Mora–Milaca. These gaps are most pronounced where potential demand is high but current service is nonexistent or indirect, often requiring multiple transfers.

Furthermore, transit coverage from county seats varies widely, with Kanabec County demonstrating strong internal and regional coverage, while Pine and Mille Lacs counties remain comparatively underserved. Directional analysis also uncovered a structural imbalance favoring north-south travel over east-west routes, with north-south movement nearly twice as prevalent. Altogether, these results highlight the need for targeted investments to expand service coverage, facilitate transfers, and enhance east-west connections to align transit availability more closely with demand patterns.

Based on the findings, we recommend the service improvements for the following four:

1. **Milaca to Mora** (new route or DRT expansion)**:**
    - **What**: 21-mile new transit route or 4.4-mile DRT service expansion via State Highway 23.

- **Gap**: The proposal addresses the second most significant transit gap.
- **How**: The proposal connects the isolated Mille Lacs County transit system (*Mille Lacs DAR*) to other East Central Area systems (via *Timber Trails DAR*).
- **Implication**: Enhances east-west transit connections.

2. **Princeton to Cambridge Route** (new route):
    - **What**: 19-mile new route via State Highway 95
    - **Gap**: Addresses the largest transit gap identified.
    - **How**: The proposal connects the isolated Mille Lacs County transit system (*Mille Lacs DAR*) to other East Central Area systems (via multiple routes serving Cambridge).
    - **Implication**: Enhances east-west transit connections.
3. **Chisago Lakes Commuter Extension to Shafer & Taylors Falls** (new route or extension):
    - **What**: 9-mile new route or extension of *Chisago Lake's Commuter* via US Highway 8.
    - **Gap**: Addresses the high potential demand and the current lack of transit services.
    - **How**: Connects Taylors Falls and Shafer (both with population over 1,000) to the county government and the Chisago Lakes-Wyoming micropolitan area (or to North Branch with transfer) with minimal extension.
    - **Implication**: Enhances east-west transit connections.
4. **Sandstone - Sturgeon Lake Extension to Carlton County's Moose Lake** (extension):
    - **What**: A 7-mile extension of the *Sandstone-Sturgeon Lake* route via local roads.
    - **Gap**: Benefits Sturgeon Lake and Willow River (populations of 462 and 395, respectively), the northern end of the current service area.
    - **How**: The proposal connects Sturgeon Lake and Willow River to the more populous city of Moose Lake (population of 3,004) that serves other county/intercity transit routes.
    - **Implications**: Moose Lake is more populous and closer to the current connection to Sandstone from the above two towns (at least 15 miles with Sandstone's population of 2,473); In addition, Moose Lake is also served by a biweekly DRT service and a Jefferson Lines Stop, connecting to Duluth and the Twin Cities.

These recommendations also ensure daily transit availability by extending services to additional towns and cities. The proposed expansion is illustrated in **Figure 9**.

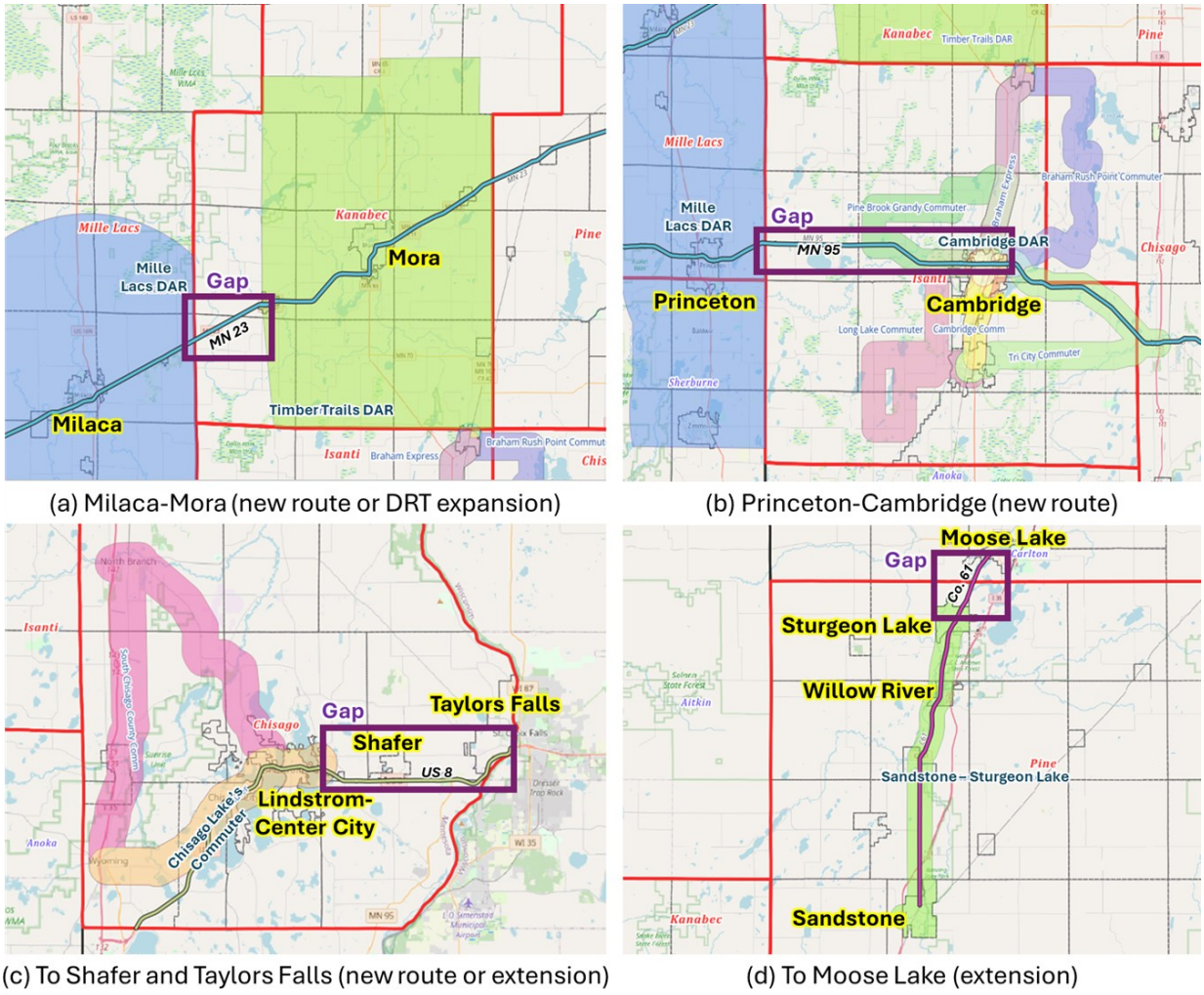


Figure 9 Four recommendations to address the identified transit gap

CHAPTER 4: CONCLUSIONS AND SUGGESTED NEXT STEPS

Addressing the identified transportation barriers will require concerted action on multiple fronts: expanding service hours and coverage areas, enhancing volunteer driver support systems, implementing legislative reforms to facilitate cross-jurisdictional coordination, and developing innovative service models tailored to rural needs. These enhancements are essential to meeting the unmet transportation needs of residents and improving mobility and quality of life throughout the region.

More specifically, this work has identified areas where these efforts can be focused, including:

- **Addressing geographic gaps**: While transit trips are available in cities like Mora during the day, people without access to their own vehicles face barriers to reaching St. Cloud, Duluth, the Twin Cities metropolitan area, and regional hubs, such as Pine City and Princeton, especially for food access and educational needs.

- **Addressing time gaps**: In cases where service is available, those without cars are unable to obtain rides outside of weekday business hours, which limits the ability to access necessary services if they also work during these hours, and/or if they need to access them on weekends.

- **Improving volunteer driver services**: volunteer drivers have traditionally provided a flexible service that filled the geographic and time gaps mentioned above, but geographic and regulatory changes have led to fewer available drivers, many of whom are getting too old to provide this service or who are unable to continue due to low reimbursement rates. This has resulted in recruiting some drivers that provide poor service, or who need more oversight than has been the case in the past.

- **Increasing awareness of existing and new services:** Conversely, this research found that some transit services are underused, due to potential riders not being aware of the opportunities. With tight budgets, providers are unable to provide sufficient marketing, perhaps focusing on low-cost social media and other digital /virtual efforts. Unfortunately, many users either do not have access to these media, either for cost or lifestyle (e.g. Seniors rely on more traditional methods, such as print or broadcast media to obtain this information).

In addition to the 4 routes identified in section 3.5, some other initial steps to meet these needs might include the following:

- **Increase availability and awareness of east-west trips** While north-south travel is available, east-west transit trips are almost non-existent. New services in this direction should be initiated, but only if resources are available to publicize the new service widely.

- **Increase availability and awareness of non-medical trips** Similarly, most trips for medical purposes are covered, and focus group participants spoke highly of many of the providers of these trips. However, trips for groceries, to see friends and relatives or for other non-medical purposes can be very hard to come by. The general transit providers offer these trips, but participants were unclear about when and where they operated, believing the options to be very limited. While higher technology tools similar to Google maps to give real-time information would be the best way to address this, simple "old school" measures like flyers at the post office, or perhaps included in utility bills are preferred over things like social media and web-pages.

- **Find ways to collaborate** In the qualitative research, we heard several examples of why things cannot work, due to various financial, administrative or other reasons. However, we heard that approaching these issues in ways that focus on organizations helping each other may create solutions that are not available to organizations relying on their own resources. For example, in the initial presentation of these findings, when some attendees noted that service initiatives failed due to lack of ridership, and lack of marketing resources, others noted funds from the Minnesota Department of Transportation may be available to support outreach and marketing activities. The difference lay in how these funds are allocated to meet needs - and that neighboring organizations may have complementary resources.

- **Continue to listen and advocate** Finally, transit service and availability is dynamic, with continued service not guaranteed year to year. Consequently, finding opportunities to tell the stories of rider needs to legislators and providers, and to facilitate communication between providers and legislators to find opportunities to innovate, collaborate and expand services is an on-going need.

APPENDIX A
DERIVATION OF TRANSIT DIRECTIONALITY

To quantify transit directionality, we analyzed the net absolute movement along the major roads for each transit route, weighted by n_r. Drawing upon the concept of a Riemann Sum or line integral, we decomposed this potential daily movement into horizontal (h_r) and vertical (v_r) components for each route r, which is computed as **Equation (1)**.

$$h_r = n_r \sum_{s \in r} |s_x| \; ; \; v_r = n_r \sum_{s \in r} |s_y| \qquad (1)$$

Where n_r is the daily transit ride availability associated with route r and s is each line segment that is a part of r, with s_x and s_y are the lengths of the horizontal and vertical components are in miles. That is, the following Cartesian decomposition holds: $|s| = \sqrt{s_x^2 + s_y^2}$.

APPENDIX B
DERIVATION OF TRANSIT GAP

Oftentimes called the "gravity model," the trip distribution model we employed is analogous to Newton's law, where the force between two objects is directly proportional to their mass and inversely proportional to the square of their distance. Our application of the gravity model to the travel demand is shown in **Equation (2)**.

$$T_{ij} = \frac{p_i p_j}{{d_{ij}}^{\alpha}} \quad (2)$$

Here, T_{ij} is the theoretical travel demand index from origin county subdivision i to destination j, p_i and p_j are the 2022 population of i and j, respectively (U.S. Census Bureau, 2022), and d_{ij} driving travel time between the two townhalls/citihalls of i and j, which is retrieved from OpenStreetMap, an online open-source map service commonly used in transportation planning and analysis via Python package OSMnx (Geoff, 2017).

To facilitate the interpretation of output range, we adjusted the parameter α in **Equation (2)**, which originally had arbitrary units and an astronomical output scale (e.g., when $\alpha = 1.5$, the value ranges from 0.0036 to 2.6 million). Specifically, we applied the logarithm to T_{ij} with base 2 and setting α to 1.5, resulting in the adjusted travel demand index now ranging from 0 to 30. However, the converted values between 0 and 20 still primarily reflected origin-destination pairs between sparsely populated towns and/or those that were excessively distant. To ensure meaningful origin-destination pairs had a travel demand index between 0 and 10 for convenient interpretation, we finalized the adjusted index by subtracting 20 from the original value. Therefore, **Equation (3)**, represents the finalized travel demand index t_{ij} from i to j.

$$t_{ij} = T_{ij} - 20 \quad (3)$$

As the index was converted using a base-2 logarithm, a one-unit difference in the index indicates that the travel demand is theoretically twice as large. For instance, index values of 6 and 8 signify a four-fold difference in theoretical travel demand.

On the other hand, impedance δ_{ij} or **Equation (4)** is defined piecewise for the two cases, depending on whether there is a direct transit connection between i and j (i.e., when there is a route r that includes any possible path l_{ij} from i to j).

$$\delta_{ij} = \begin{cases} \frac{1}{1 + \Sigma_{l_{ij} \in r} n_r}, & if\ \left|\{r | l_{ij}\ \in r\}\right| > 0 \\ else & max\ (5, (transfers\ required\ for\ i \to j)\ ), \end{cases} \quad (4)$$

Using only weekday routes in the calculation of **Equation (4)**, we designed a higher impedance value to signify lower actual transit connectivity. In addition, we ensured the resulting numbers to be continuous across the two piecewise cases (the presence of a direct transit connection, or when $\left|\{r | l_{ij}\ \in r\}\right| > 0$). For instance, if there are two and one daily transit trips (combined regardless of the routes) available between i and j, the upper part of the equation yields values 0.33 and 0.5, respectively. With an extreme case of only one monthly route is available ($n_r = 0.05$, assuming there are 20 weekdays in a month), the value becomes $1/(1 + 0.05) = 0.952$, yielding the value near 1, which implies a transfer is needed.

For scenarios lacking a direct transit connection (represented by the lower part of the equation), we ensured the calculated numbers remained continuous across both piecewise cases, accurately reflecting the practical impedance. To achieve this, when determining the number of transfers, we first eliminated routes with less-than-once-a-day frequency. Including such routes with weekly or monthly frequencies at the first place would misleadingly suggest guaranteed transfers, even when no connecting service is available on a given day, thereby misrepresenting the true impedance.

In addition, all routes with more than one daily frequency are treated equally in our number of required transfers calculations. This means a route running hourly is weighted the same as one running daily, provided they offer the same geographical connection for a given origin-destination pair. We made this choice for several reasons:

- When planning a trip involving a transfer, people are most likely to prioritize routes with the lowest frequency as the schedule of which is most binding.
- In the ECRDC region, opportunities to transfer between two highly frequent routes are rare.
- Even when such a transfer is possible, timetable-based operations make the transfer opportunity rarer and it also significantly vary throughout the day.

Finally, we adjusted the non-direct δ_{ij} values for mixed-frequency cases, where the inclusion of weekly or monthly routes could reduce the number of transfers on certain days. For instance, consider an origin-destination pair that typically requires two transfers when only daily routes are factored in. If this same trip can be completed with just one transfer by combining a daily route with a weekly route, we do not simply assign a δ_{ij} value of 1 or 2. Instead, we use 1.83. This value is derived by adding 1

(representing the single daily transfer) to $1/(1 + 0.2)$, with the latter term accounting for the contribution of the weekly route as determined by the upper part of our equation.

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