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Leveraging semi-flexible demand-responsive transport for efficient student commutes in underserved communities: a case study

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Abstract

Purpose – This paper evaluates how a semi-flexible demand-responsive transport (DRT) design, combined with fixed-route school bus optimization, can improve high-school commute accessibility in low-density and underserved areas of El Paso, Texas, USA.

Design/methodology/approach – The analysis integrated Geographic Information Systems, the Google Maps Directions Application Programming Interface, General Transit Feed Specification datasets, school attendance zones, and school bus route information. The analysis first assessed existing public transit and school bus accessibility, then identified low-demand bus stops, formed DRT service zones, tested stop consolidation rules, and restructured affected fixed routes.

Findings – The results indicate that a school commute-oriented, semi-flexible DRT concept can reduce travel time for low-demand areas when paired with fixed-route restructuring. Five DRT zones were identified. The largest modeled benefits occurred where low-demand stops were spatially clustered and could be served by smaller vehicles without retaining long fixed-route deviations. The analysis also shows that some benefits arise from route optimization rather than demand responsiveness alone.

Research limitations/implications – The analysis is limited to planning-level modeling for the school district in El Paso and relies on available route, stop, and travel-time data. It does not include primary interviews with students, school staff, or transit operators; observed DRT ridership; or a full cost-benefit assessment. These issues are identified as priorities for pre-implementation testing and future research.

Originality/value – The study contributes to the DRT literature by examining a relatively underexplored application: semi-flexible DRT service design for high-school commutes in an underserved, low-density border-city setting. It evaluates how predefined low-demand zones, smaller vehicles, and fixed-route restructuring can be assessed collectively without treating the intervention as a fully dynamic DRT service.

Keywords Public transport, Travel time, Network planning, Demand-responsive transport

Paper type Research article

1. Introduction

Reliable and efficient transportation is vital to human development, providing essential access to employment, education, and healthcare (Giuliano and Hanson, 2017; Polyzos and Tsiotas, 2020; Rodrigue, 2024). Transportation options heavily influence students' ability to attend school, perform academically, and participate in extracurricular activities. However, traditional transportation systems face many challenges when attempting to meet the many needs of the community they serve, with rigid schedules, limited coverage, and inefficiencies in route design. This is particularly true for areas with low population densities, where the demand is too low for a fixed transportation network, making it expensive to operate with insufficient coverage (Bar-Yosef *et al.*, 2013; Lu *et al.*, 2023). These areas with low coverage

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and low-frequency routes have long travel times and create a dependency on personal automobiles to satisfy mobility needs. Furthermore, this creates barriers to accessing educational opportunities, affecting students who are part of vulnerable populations or underserved communities (Lu *et al.*, 2023).

Studies have examined the feasibility of flexible transport, cost and subsidy requirements, service reliability, user acceptance, rural accessibility, and integration with fixed-route transit (Brake *et al.*, 2007; Davison *et al.*, 2014; Mulley and Nelson, 2009; Schasché *et al.*, 2022; Sorensen *et al.*, 2021; Zahedi *et al.*, 2024). Many of these studies focus on operational efficiency, user acceptance, and integration with existing public transit networks (Davison *et al.*, 2014; Wong *et al.*, 2020; Zahedi *et al.*, 2024). In contrast, few studies have explicitly addressed school commutes in low-density or rural settings. Lu *et al.* (2023) modeled DRT for student trips in a rural district in Germany and demonstrated its cost-effective potential under realistic operating assumptions. Zhao *et al.* (2024) explored the role of DRT for young people's school and leisure journeys, emphasizing mobility equity and accessibility in rural contexts. Furthermore, studies on flexible and on-demand transport in rural Australia highlight persistent operational, financial, and policy barriers that limit the broader adoption of DRT, barriers that would similarly constrain potential applications such as student commutes. (Loyola and Nelson, 2025). These findings present the research gap and the need for tailored DRT strategies to improve school accessibility in low-density regions.

The main goal of this study is to assess how a semi-flexible DRT service concept, integrated with fixed-route school bus optimization, can mitigate the gaps in student commute accessibility in a low-density border-city context. The specific objectives of this study are: (1) to evaluate the accessibility of existing local fixed-route public transit and school bus services in El Paso, Texas; (2) to identify service gaps and low-demand stops that hinder efficient student mobility; and (3) to design and evaluate a semi-flexible DRT-zone and route-optimization strategy that can address selected limitations of the current network.

The case study is focused on the City of El Paso, Texas, and the El Paso Independent School District (EPISD). El Paso is a useful case for this analysis because it combines a border-city setting, low-density residential development, uneven walkability, and a large student population with substantial transportation needs. These conditions create a context in which conventional fixed-route school transport can be difficult to operate efficiently, but a fully dynamic DRT system may also face practical constraints. The study therefore models a semi-flexible school transport network design in which low-demand stops are grouped into DRT zones served by smaller vehicles, while affected fixed routes are restructured to reduce unnecessary duplications.

The paper is organized as follows. Section 2 reviews DRT, flexible transport, and student-focused applications. Section 3 presents the methodology and explains the case-study design, data sources, accessibility analysis, DRT-zone formation and key assumptions. Section 4 describes the El Paso case context. Sections 5 and 6 present analytical results, discuss the proposed DRT network design, and examine modifications to the current El Paso Independent School District (EPISD) school bus system. Section 7 discusses the findings implementation feasibility and practical implications. Section 8 concludes the paper and identifies limitations and future research needs.

2. Demand-responsive transit (DRT)

Demand-responsive transit (DRT), also known as flexible transport or microtransit, refers to public or shared transport services in which routing, scheduling, or stop patterns respond to passenger demand rather than following only a fixed timetable and fixed routes (NASEM, 2013; Sorensen *et al.*, 2021; Raveau, 2021; Dytckov *et al.*, 2022). DRT is not a single operating model. It can range from fully flexible door-to-door services to route-deviation services, point-deviation services, semi-fixed shuttles, and pre-booked feeder services. It has gained popularity in recent years due to its adaptability and ability to address service gaps in traditional fixed-route transit systems, particularly in low-density or hard-to-serve areas and during off-peak times (Mulley and Nelson, 2009; FTA, 2020; Shaheen and Cohen, 2020).

Fixed-route transit systems, while effective in high-density urban environments, lose efficiency and cost-effectiveness as population and development density decrease. In suburban or rural areas, the sparse distribution of demand makes traditional transit infeasible without substantial subsidies (Litman, 2021). In this context, DRT emerges as a viable alternative, enabling transit agencies to more closely match supply with actual demand. By servicing riders only when and where they are needed, DRT enhances mobility and fills the first-mile/last-mile gaps often left by fixed-route networks (Brake *et al.*, 2007; Shaheen *et al.*, 2016). From a transportation equity perspective, DRT offers important social benefits. Many low-income households, older adults, and people with disabilities reside in transit deserts, where conventional public transportation is limited, infrequent, or unavailable. For these groups, access to affordable and reliable transportation is often a barrier to employment, education, and healthcare. The introduction of DRT systems can mitigate these barriers, expanding transit access to underserved communities and promoting greater social inclusion (Alonso-González *et al.*, 2018; Deka *et al.*, 2023; Thao *et al.*, 2023). Furthermore, the affordability of DRT systems makes them especially appealing to low-income individuals. According to the Bureau of Transportation Statistics, transportation is the second-largest household expenditure in the US, often accounting for more than 30% of income among the lowest quintile of earners (BTS, 2022).

Recent rural DRT studies provide useful context for this research. Sorensen *et al.* (2021) showed that rural DRT performance depends strongly on the degree of service flexibility, because greater flexibility may improve spatial coverage but can also create uncertainty in pick-up times, routing, and user expectations. Dytckov *et al.* (2022), using a simulation-based analysis in rural Denmark, further demonstrated that DRT can improve service availability in low-demand settings, although the benefits depend on demand density, vehicle availability, and routing assumptions. Schasché *et al.* (2022) reached a similar conclusion by showing that rural DRT systems often have to balance between user expectation and service coverage within reasonable cost and staffing limits. Related optimization studies also provide useful support for the routing logic. Shu *et al.* (2021) demonstrated how last-mile shuttle service may be improved when stop locations, travel times, and passenger demand are considered together. Martí *et al.* (2023) similarly showed that transfer-point allocation can improve rural demand-responsive transportation by reducing inefficient routing patterns. These studies support the use of stop clustering, stop consolidation thresholds, and route optimization as planning tools for low-demand service areas.

While recent rural DRT studies provide important guidance on service flexibility, demand density, schedule reliability, and operating constraints, student-focused applications remain limited. Lu *et al.* (2023) modeled DRT for students in the rural Vulkaneifel district in Germany and found that a door-to-door school transport model could be feasible, although cost and fleet requirements remained central concerns. Zhao *et al.* (2024) examined the potential of DRT for young people’s school and leisure journeys and reported that flexible routing and door-to-door service could improve competitiveness relative to conventional transport options. These studies indicate that DRT may have value for student mobility, but they also show that the design must be based on careful assumptions about demand, routing, vehicle capacity, and institutional responsibility. School transport differs from general-purpose DRT because trips are tied to fixed bell schedules, student safety requirements, recurring peak-period demand, and changes in ridership as students graduate, move, or change schools. This creates a specific research gap for planning-level methods that can identify where semi-flexible DRT or route-deviation services may be appropriate for high school commute needs in low-density and underserved urban areas.

Several transportation authorities around the world are exploring innovative funding and operational models that merge school transportation services with general-purpose DRT systems. Traditionally, school districts or municipalities have allocated separate budgets for dedicated school bus fleets, which often sit idle during off-peak hours. An emerging alternative is the use of a shared fleet model, where smaller vehicles such as minivans or passenger cars are deployed for student transport during morning and afternoon peak periods and then repurposed for public DRT use throughout the rest of the day. This dual-purpose utilization could significantly expand the size and availability of DRT fleets without requiring additional investment in new vehicles. As a result, the overall service could become more reliable and accessible, thereby increasing user satisfaction and ridership. Simultaneously, the model offers operational efficiencies and cost savings, relieving the financial pressures often faced by DRT operators (Nyga *et al.*, 2020; Lu *et al.*, 2023).

3. Methodology

3.1 Research design

This study is conducted to assess whether a semi-flexible DRT concept can address the gaps in student commute accessibility in a specific local context. Following Yin's (1994) case study approach, this study examines El Paso as a context-specific case where school transport accessibility, low-density urban form, and underserved student's mobility needs are closely linked. Also, the case study design is appropriate because the proposed DRT-based intervention cannot be evaluated independently from the local roadway network, school attendance zones, existing bus routes, and spatial distribution of student demand.

In this study, a DRT zone refers to a predefined low-demand service area formed by clustering school bus stops with small, estimated demand. Flexi-stops refer to low-demand stops assigned to the semi-flexible service rather than retained on the conventional fixed school bus route. Proposed routes refer to the modeled routes within each DRT zone that would be served by smaller vehicles, such as vans. Restructured routes refer to the remaining fixed school bus routes after DRT-zone stops are removed and the affected routes are revised to reduce unnecessary deviations.

The methodology was organized to align with the three research objectives. Objective 1 was addressed through GIS- and GTFS-based service area analysis for public transit and EPISD's school bus routes. Objective 2 was addressed by identifying low-accessibility areas, low-demand stops, and route segments where fixed-route service produced long travel times relative to the number of students served. Objective 3 was addressed through semi-flexible DRT zone design, stop consolidation, travel-time estimation, and restructuring of affected fixed routes. The workflow is shown in Figure 1.

3.2 Data collection and cleaning

The study began with the extraction of all relevant transportation and geographic datasets required for the analysis. The study used three primary data sources (Table 1): City of El Paso Open Data Portal datasets for roadway networks, transit infrastructure, and city boundary shapefiles; GTFS datasets for Sun Metro routes, stops, schedule, and headway information; and school attendance zone and school bus's route information for EPISD. EPISD bus route information was originally available in PDF format and was converted into a GTFS-compatible structure to support service area analysis. GTFS files were checked for missing values, formatting inconsistencies, duplicate stops, and structural issues that could affect network analysis.

Student counts near EPISD bus stops were used as planning-level demand indicators. A buffer of 800 m (0.5 mile) was drawn around each school bus stop, and the number of students living within that buffer was used to estimate potential walk-up demand at the stop. Stops with estimated boarding demand of five or fewer students were classified as low-demand candidate stops. These stops were exported into a separate GIS layer for DRT-zone formation. Bus stops that had an estimated boarding demand of ≤ 5 students were identified and were exported as a new layer.

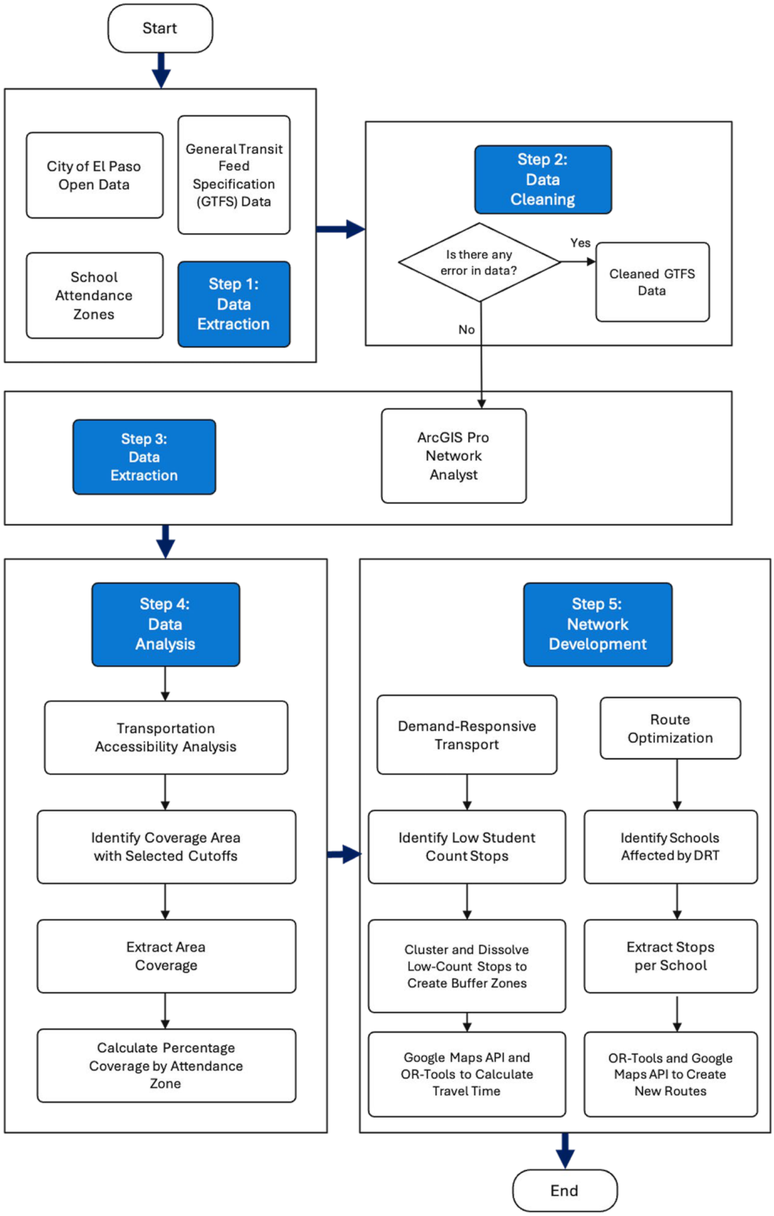


Figure 1. Research methodology. Source: Authors' work

3.3 Accessibility and service gap analysis

Service area analysis was used to evaluate accessibility and service gaps under existing public transit and school bus conditions. The network was modeled for arrival at school by 8:25 a.m. on a Wednesday, using 15-, 30-, and 45-minute travel-time thresholds. These thresholds were selected to represent short, moderate, and extended commute windows for high-school students. Isochrones were generated to estimate the spatial area that could reach each school

Table 1. Data summary

Data	Format	Source
Sun Metro GTFS	GTFS (.txt)	Mobilitydatabase.org
EPISD bus routes	PDF	EPISD (2024)
El Paso Schools	Shapefile	City of El Paso Open Data (2020a)
EPCenterline	Shapefile	City of El Paso Open Data (2020b)
Network Dataset Template	XML	Esri ArcGIS
School Attendance Zones	Shapefile	EPISD, YISD, SISD
US Census Blocks	Feature Layer	USC Data (2023)

within each travel-time threshold. Results were then compared across EPISD, Ysleta Independent School District (YISD), and Socorro Independent School District (SISD) and examined in greater detail for EPISD.

Travel times were estimated from roadway network and schedule data rather than from observed student trips. This method is appropriate for planning-level screening, as used in this case study, but it does not fully account for daily congestion variation, walking conditions, household travel decisions, or student and family preferences for DRT compared with existing school buses or parental drop-off. These limitations are discussed further in the discussion and conclusion sections.

3.4 Semi-flexible DRT zone design and routing procedure

Candidate low-demand stops were clustered into preliminary service zones using overlapping 800 m buffers to identify broader low-demand areas around the school bus stops. Within each zone, stops within 400 m were tested for consolidation to reduce route length and travel time while retaining reasonable walking access. The 400 m rule was applied as a practical stop-consolidation threshold and was only retained when it improved or did not materially worsen route performance. A 15-passenger van was assumed to serve each DRT zone. The maximum number of students assigned to a zone was set at 37 because EPISD's approximate 40% school-bus ridership implies an expected load of about 15 students (37 x 0.40 = 14.8). According to Taylor *et al.* (2021), the average school bus ridership in Texas is 32%. The actual percentage varied across school districts, with 40% as the mode. Therefore, the 40% assumption was used only for capacity screening. The actual number of student riders may vary annually depending on changes in district enrollment. It does not imply that all 37 students would request the DRT service on a given day, nor does it establish long-term demand stability. Expected ridership was also tested under 30%, 40%, and 50% demand scenarios. This sensitivity check suggested that the proposed DRT-zone design is reasonably robust for planning purposes, although actual ridership would need to be confirmed before implementation.

The Directions API was used to visualize routes between consecutive stops and to compute both travel time and total route distance. Each stop was represented as a coordinate pair $s_i = (x_i, y_i)$. For every ordered pair of stops (s_i, s_j), the travel time T_{ij} and travel distance D_{ij} were obtained through an API request of the form $API(s_i, s_j) \rightarrow \{T_{ij}, D_{ij}\}$. A custom Python script automated this process by iterating through all pairs of stops (s_i, s_j) generating route queries of the form and parsing the returned JSON structure to extract travel time and distance: $URL_{ij} = DirectionsAPI(s_i, s_j, API\_key)$. The routing objective was to minimize morning in-vehicle time while respecting school arrival time, vehicle capacity and zone boundaries.

After DRT-zone formation, stops assigned to DRT service were removed from their original school bus routes. Affected fixed routes were then restructured to remove unnecessary duplications and improve travel time for remaining riders. Results are reported in two categories: (1) changes attributable to the semi-flexible DRT-zone design for low-demand stops and (2) changes attributable to fixed-route restructuring after those stops were removed. This information was added to avoid overstating the effect of demand responsiveness alone.

4. Case study: city of El Paso, Texas

This study centers on the City of El Paso, Texas, which provides the geographic context for the research. The city sits on the Rio Grande along the Mexico–U.S. border, across from Ciudad Juárez, Chihuahua. El Paso also borders Las Cruces, New Mexico, on the US side, and along with Ciudad Juárez, these three cities form the Paso del Norte metropolitan area or Borderplex region. El Paso has experienced steady growth over the years and, as of 2024, boasts a population of 681,723 across 255 square miles (U.S. Census Bureau, 2024). With approximately 81% of its residents identifying as Hispanic, El Paso has the second-highest Hispanic population among US cities, following San Antonio, Texas.

4.1 Land use

El Paso is surrounded by the Franklin Mountains and is located in the Chihuahuan Desert, which creates physical constraints for land use and transportation planning. The city has a large geographic footprint and relatively low population density. The traditional fixed-route transit networks are not as effective because of the low demand throughout El Paso and can be incredibly expensive. The city consists mostly of single-family households, which do not make a viable demand for extensive and frequent fixed transportation routes. The majority of residential areas are low- to medium-density developments with sprawling suburban areas. The central district of El Paso is characterized by its higher density and commercial activity, with a mix of retail, office, and recreational spaces. However, mixed-use development in El Paso is minimal and is mostly confined to the downtown area of El Paso.

4.2 Walkability ranking

El Paso's infrastructure has progressed over the years to promote walkability and active transportation. Neighborhoods like Union Plaza, Chihuahuita, and Virginia are highly walkable and have access to good public transportation (El Paso Neighborhoods on Walk Score, 2024). However, El Paso continues to be a city with low walkability, ranking 26th most dangerous city for pedestrians (Smart Growth America, 2022). The walkability of a city is a great influencing factor in public transportation demand, as commuters want to feel safe while walking towards the public transport network or to their destination from the public transport network. Poor walkability, therefore, reduces the demand for fixed-route networks, further making these networks unsustainable and unjustifiable in areas where people are not able to or are unwilling to walk due to poor pedestrian infrastructure. As a result, El Paso is a car-centric city with a high car dependency for most, if not all, employment, education, and social activities.

4.3 El Paso school districts

The El Paso schooling system consists of three main school districts: EPISD, YISD, and SISD (Figure 2). El Paso school demographics for 2022–2023 can be seen in Table 1. EPISD is the largest school district in El Paso in terms of student population, followed by SISD and YISD. All the districts face some serious socio-economic challenges, and the majority of the students are part of a disadvantaged group. The student population is largely Hispanic, with YISD having the largest Hispanic population of all the districts. It also has the largest economically disadvantaged student population, where students are considered economically disadvantaged based on whether they receive free or reduced lunch or some type of public assistance. EPISD has a dropout percentage higher than the state average, and it is also the district where students are most at risk of dropping out. Graduation percentages for YISD and EPISD are lower than the state percentage. All high schools in El Paso are classified as Title l, which is a federal

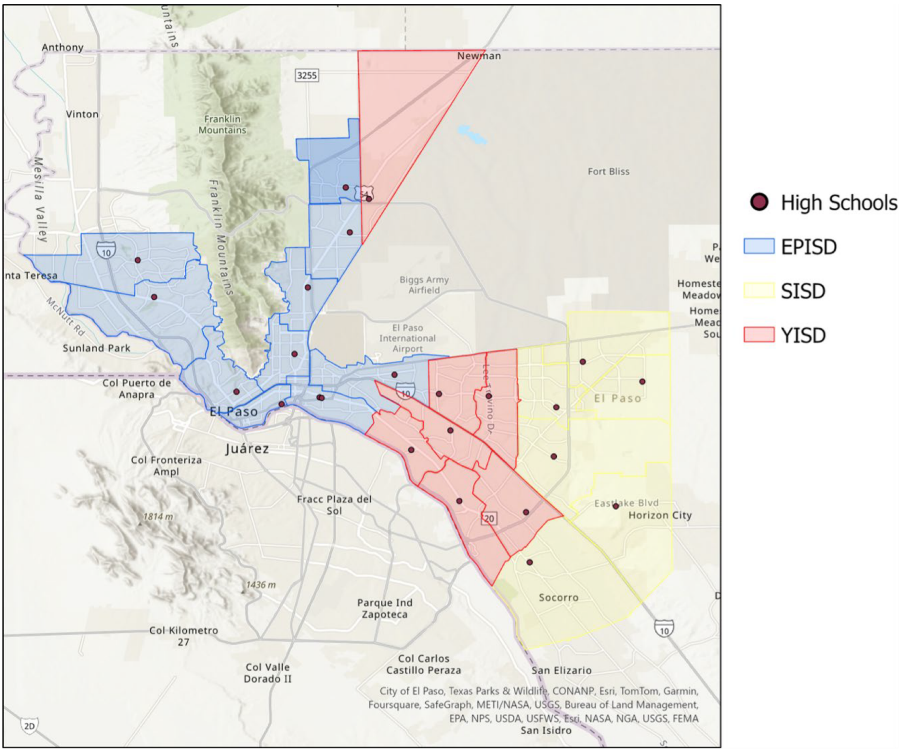


Figure 2. El Paso school districts (EPISD, 2024; SISD, 2017; YISD, 2024). Source: Authors' work

program providing funding for schools with a high percentage of socio-economically disadvantaged students.

5. Service area analysis

5.1 Public transit service analysis within school districts of El Paso

To address Objectives 1 and 2 of the case study, service area parameters were established to evaluate public transit accessibility within specific travel-time thresholds. The transit network was modeled to simulate arrival at school by 8:25 a.m. on a Wednesday, using 15, 30, and 45-minute travel times to assess the spatial reach and coverage of the system. This was done to model the journey of a high school student on a typical school day. The isochrones were created to indicate the areas that were covered within the specified travel time (Figure 3).

The comparative analysis of the EPISD, YISD, and SISD school systems highlights clear distinctions in the relationship between accessible area and transit coverage within each district. Most EPISD schools (Figures 4(a–c)) show a moderate correlation between enrollment area and transit coverage, where larger service areas such as Austin and Jefferson high schools demonstrate higher coverage percentages, particularly within the 15-minute and 30-minute accessibility zones. This pattern suggests that EPISD schools get benefit from relatively balanced urban coverage, with accessibility improving gradually as travel time increases. However, the 45-minute coverage indicates saturation, implying that extended travel times do not substantially enhance reach within this district.

In contrast, the YISD and SISD (Figures 4(b) and 4(c)) show more pronounced variability across schools, reflecting distinct geographic and infrastructural contexts. YISD schools such

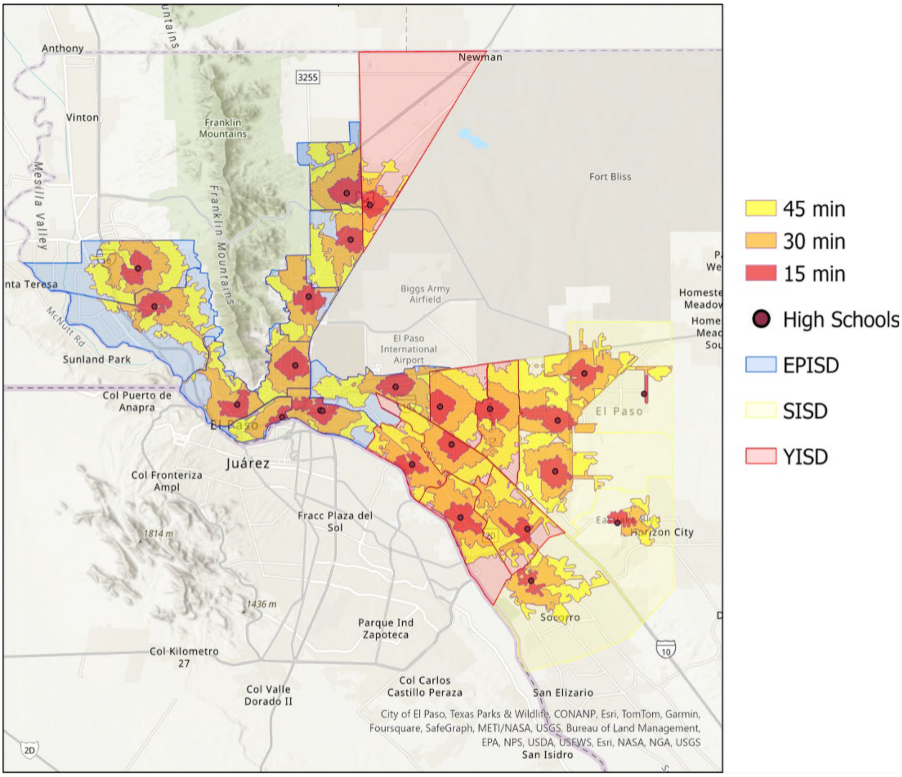


Figure 3. Sun Metro Isochrone Map. Source: Authors' work

as Riverside and Del Valle exhibit high coverage growth at longer travel times, indicating broader catchment areas and potentially less compact neighborhoods. Conversely, SISD schools display wider dispersion in both areas and coverage, with Montwood and El Dorado achieving high accessibility and transit reach across all intervals, while Pebble Hills and Eastlake exhibit markedly lower levels of transit reach. This suggests that SISD's accessibility is influenced by suburban spatial distribution, where certain schools are well-integrated into transit networks while others are relatively isolated.

5.2 EPISD bus service analysis

EPISD is the largest school district in the region, serving the highest number of students and encompassing a substantial proportion of vulnerable and transportation-disadvantaged populations. It represents a critical and high-impact setting for examining the implementation of demand-responsive network zones, so it was selected to conduct an in-depth case study. EPISD has a total of 54 routes servicing their high schools with two trips per route, one in the morning before school and one in the evening after school. The process adopted for analyzing the accessibility of EPISD bus routes was the same as the process for analyzing the accessibility of the Sun Metro transit network. The parameters for the service area analysis were also set to arrive at school at 8:25 a.m. on a Wednesday, with travel times of 15, 30, and 45 minutes (Figure 5(a)). The analysis shows that the 15-minute travel time average area was 2.87 km^2, the maximum area was 4.44 km^2 for Coronado High School, and the minimum area was 2.07 km^2 for Bowie High School. The average service area coverage for a

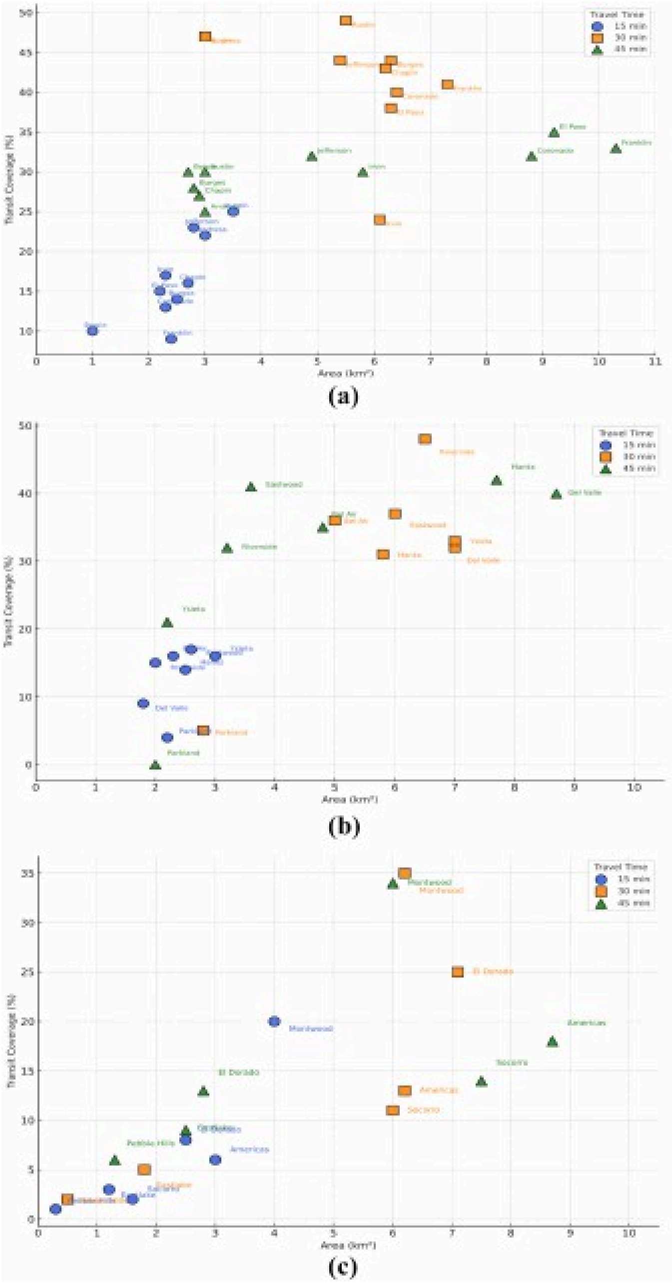
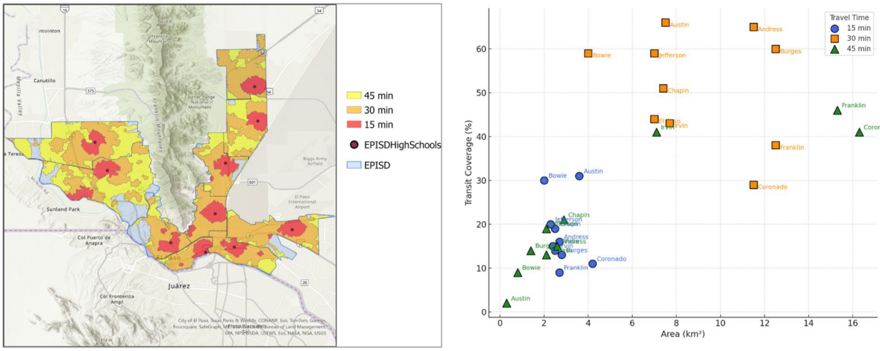


Figure 4. Public transit coverage and accessible area (a) EPISD; (b) YISD; (c) SISD. Source: Authors' work

30-minute travel time was 8.94 km^2, the maximum area was 12.58 km^2 for Franklin High School, and the minimum area was 3.99 km^2 for Bowie High School. Lastly, within a 45-minute travel time, the average area was 5.31 km^2, the maximum area was 16.46 km^2 for



(a) (b)

Figure 5. (a) EPISD Isochrone Map; (b) EPISD Bus Coverage and Accessible Area. Source: Authors' work

Coronado High School, and the minimum coverage area was 0.22 km^2 for Austin High School. Notably, the majority of the coverage area falls within the 30-minute travel time. Austin High School is the school with the highest percentage of coverage and, as a result, has the highest level of accessibility. It is interesting to note that schools that had ranked high in the 15-minute travel time are at the bottom in the 45-minute travel time, and vice versa (Figure 5(b)).

The service analysis shows considerable variation among EPISD schools, indicating that transit coverage is not evenly distributed across the district. Most of the effective coverage occurs within the 30-minute travel window, suggesting that this threshold represents the practical limit of the current network's reach. Performance across the 15-, 30-, and 45-minute thresholds is highly nonlinear, with some schools ranking high in short-distance accessibility but falling significantly in longer travel-time areas, and vice versa. This inversion highlights differences in neighborhood density, network structure, and spatial configuration. These patterns show the presence of substantial spatial inequities and point to the need for more adaptable mobility solutions to address the gaps in areas where fixed routes do not adequately meet student needs.

6. Semi-flexible DRT network design and route optimization

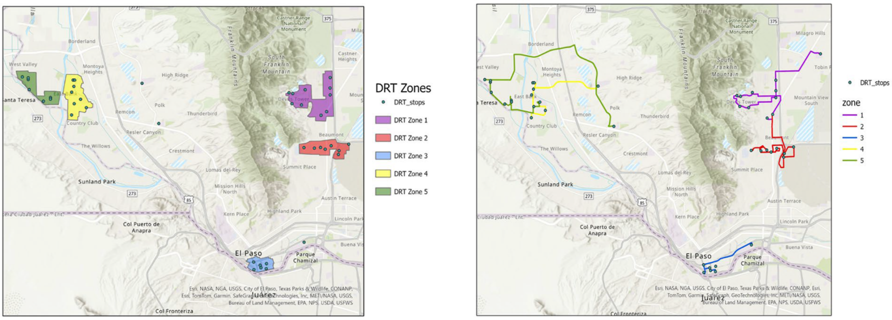
The El Paso Independent School District is the largest district in El Paso and serves a large number of students who face socio-economic challenges (limited English proficiency, economically disadvantaged, and at risk of dropping out) and children of Fort Bliss families. The district also contains some of the poorest zip codes in the United States, further highlighting the vulnerability of the EPISD student population. Serving approximately 50,000 students across 71 campuses (EPISD, n.d.), EPISD was assumed to have a bus ridership rate of approximately 40%. Under this assumption, about 20,000 students rely on district transportation each day, reflecting the district's socioeconomic conditions and operational context. EPISD was chosen for the development of DRT network zones and route optimization to better serve their students and reduce overall travel times.

6.1 DRT zones and routes

For the development of each DRT network, zones were created around stops with a student count of five students or fewer that had been clustered together with buffers of 800 meters. Assuming that a 15-passenger van is going to be servicing these areas, similar stops were selected within these zones so that the number of students serviced per zone did not exceed 37 students (which at 40% ridership would be 15 students). Five DRT zones were identified

(Figure 6(a)): two in northeast El Paso, one in central El Paso, and two in west El Paso. Zones 1 and 2 serve Irvin and Chapin High Schools. Zone 3 serves Bowie High School. Zones 4 and 5 serve Franklin and Coronado High Schools. For Zones 2 and 3, stops within 400 m were combined because consolidation reduced travel time. For Zones 1, 4, and 5, consolidation did not materially change travel time, and the route alignment remained effectively the same with or without combined stops. The proposed routes for each DRT zone are shown in Figure 6(b).

Table 2 shows the maximum duration it would take for a van to complete a trip if all stops are included, as well as the number of students that the DRT zone serves. Table 3 shows the travel time of the route the stops originally belonged to, their student count, and the DRT zone that they are in. The zones that saw the biggest reduction in travel time compared to the original routes are zones 3, 4, and 5. The difference in travel time between Route 154C, the shortest route in zone 3, and the proposed DRT zone 3 is 13 minutes. Although the difference between the shortest route in zone 4 and the proposed DRT zone is only a minute, the difference between the next shortest route and the DRT zone is 14 minutes. For zone 5, the difference between its shortest route and the proposed zone is 17 minutes. Zones 1 and 2 do not show major differences in travel time; in fact, there is a travel time increase for some of the routes. In zone 1, there is an increase of 7 minutes in overall travel time from the shortest route in that zone and the proposed zone. However, as previously mentioned, this zone serves Irvin and Chapin High School. From the first pick-up spot to Chapin High School, Chapin students would have a total travel time of 17 minutes. Travel from the initial pickup stop to Irvin High School results in a total travel time of 17 minutes for students. That is a 17-minute and 10-minute travel time reduction from both routes that are in zone 1. Zone 2 also sees an increase in travel time, but coupled with the optimization of routes for Chapin High School, there is a decrease in travel time for students.



(a) **(b)**

Figure 6. (a) Proposed DRT zones; (b) Proposed DRT zone routes. Source: Authors' work

Table 2. DRT travel time

DRT zone	Duration (min)	Student count
1	34	37
2	30	22
3	14	27
4	27	27
5	31	30

Table 3. Route travel time

Route	Duration (min)	Student count	DRT zone
R301C	34	99	1
R314C	27	25	1
R307C	17	59	2
R305C	21	126	2
H300C	39	64	2
R161C	32	47	3
R179C	32	60	3
R154C	27	55	3
R421C	55	172	4
R419C	41	47	4
R413C	28	74	4
R415C	54	65	5
R401C	48	119	5

6.2 Restructured school bus routes

Since the stops in the DRT zones will no longer be served by regular school buses, these stops were removed from existing school bus routes. This route revision resulted in shorter school bus routes and faster maximum travel times. Figure 7 shows the 7 redesigned school bus routes serving Chapin, Irvin, and Bowie High Schools. The restructuring of school bus routes was repeated for other routes impacted by the introduction of DRT service.

Table 4 compares current and proposed routes, including duration, possible student load, and route changes. Initially, 12 routes served Irvin, Chapin, and Bowie High Schools. After DRT-zone creation and route optimization, the number of routes was reduced to seven. Most routes show travel-time reductions between 6 and 20 minutes, while Route R316C increases by one minute and Route 307C increases by seven minutes. The increase for Route 307C should be interpreted in relation to the broader Chapin network, where average student travel time decreases from 28 to 21 minutes (Table 5). Bowie High School shows the largest average reduction, with a 10-minute improvement.

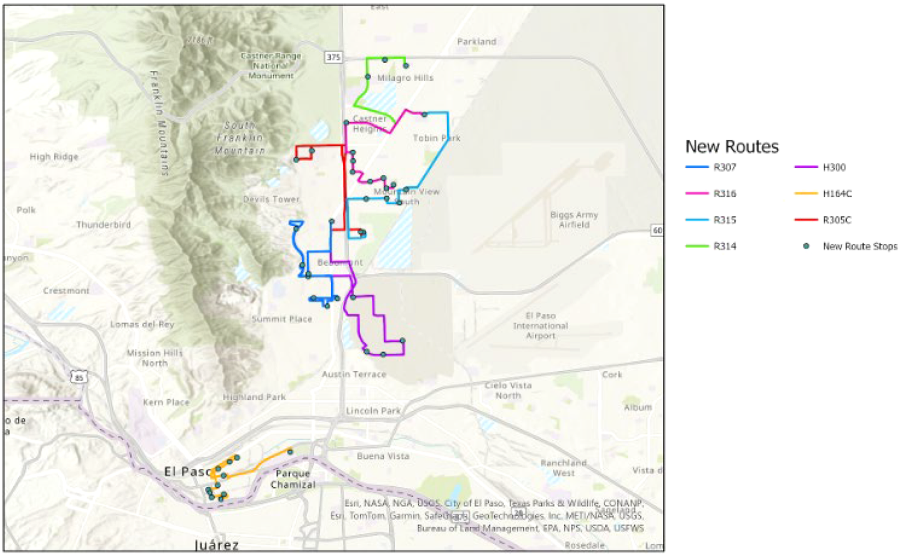


Figure 7. New proposed routes. Source: Authors' work

Table 4. Current vs. proposed routes

Route	Current Duration (min)	Student count	Proposed Duration (min)	Student count	School	Comments
R301C	34	99	0	0	Chapin	Removed
R314C	27	25	10	9	Irvin	Exchanged for a van
R307C	17	59	24	170	Chapin	Combined R301C, R305C and R307C
R305C	21	126	14	78	Chapin	Combined R305C and R301C
H300C	39	64	24	56	Chapin	
R161C	32	47	0	0	Bowie	Removed
R179C	32	60	0	0	Bowie	Removed
R154C	27	55	0	0	Bowie	Removed
R315C	22	83	14	118	Irvin	Combined R315C and 304C
R304C	20	77	0	0	Irvin	Removed
R316C	13	44	14	87	Irvin	Combined R315C and R316C
R164C	23	35	19	170	Bowie	Combined all Bowie routes

Table 5. Current vs. proposed travel time averages

	Avg travel time (min)		Student count	
	Current	Proposed	Current	Proposed
Chapin	28	21	87	102
Irvin	21	13	58	72
Bowie	29	19	50	170

7. Discussion

This study shows that a semi-flexible DRT service concept, used together with fixed-route restructuring, can improve the efficiency of school transport in selected low-density areas. The main finding is that low-demand stops can place a disproportionate burden on conventional school bus routes when they require long deviations for a small number of students. By grouping these stops into defined DRT zones and assigning them to smaller vehicles, the proposed approach reduced unnecessary route deviations and improved travel time performance for several affected schools.

The efficiency gains were observed in two related ways. First, the DRT-zone design provided a more direct service option for dispersed low-demand stops that were difficult to serve efficiently through conventional bus routes. Second, once those stops were removed from the fixed-route network, the remaining school bus routes could be restructured with shorter and more direct paths. The modeled improvements were not produced by demand responsiveness alone. They resulted from a combined service design in which semi-flexible DRT handled selected low-demand segments, while the fixed-route system continued to serve higher-demand corridors. The results provide a planning basis for identifying where this type of service may be most appropriate. Candidate areas are likely to have clustered low-demand stops, long fixed-route deviations, limited walking access to consolidated stops, and student populations for whom shorter commute times have educational and equity implications. In the El Paso case, these conditions were present in parts of the EPISD service area, where low-density development and uneven transit coverage create long student commute times. The reduction from 12 to 7 routes for Irvin, Chapin, and Bowie High Schools indicates that the proposed design can improve modeled operational efficiency while preserving planned service coverage for the student locations included in the analysis. The travel-time reductions identified for several schools further suggest that the combined semi-flexible and fixed-route design may improve modeled commute performance without requiring districtwide network restructuring.

These findings are consistent with selected principles in the DRT literature, particularly the importance of matching service flexibility, vehicle capacity, stop patterns, and route design to spatially dispersed demand (Brake *et al.*, 2007; Sorensen *et al.*, 2021; Schasché *et al.*, 2022). The study also aligns with student-focused DRT research by Lu *et al.* (2023) and Zhao *et al.* (2024), which suggests that flexible service can support school and youth mobility under appropriate design conditions. The study therefore provides evidence for a semi-flexible, demand-informed school-transport planning approach rather than for a fully dynamic public DRT operation. The workflow identifies where the existing fixed-route system appears inefficient and where smaller vehicles or route-deviation models may offer a better service fit.

The review of existing studies presents that the type of DRT that is most relevant for school transport. A fully demand-responsive, open door-to-door model may not be the best option for school commutes because student trips are tied to bell schedules, safety requirements, and predictable morning and afternoon travel periods. The proposed model for EPISD is therefore better understood as semi-flexible DRT. It uses predefined service zones, selected flexi-stops, smaller vehicles, and fixed arrival-time requirements. This structure preserves some of the operational discipline of school bus service while adding flexibility where the fixed-route system is least efficient.

From the implementation perspective, two important planning aspects should be noted that were beyond the scope of this study. First, operating and maintenance costs, driver availability, vehicle procurement, scheduling software, and supervision would need to be assessed before service deployment. Institutional responsibility would also need to be clearly defined, whether the service is operated by the school district, a public transit agency, or a contracted provider. These considerations are not unusual for DRT systems, but they are especially important in student transport because service reliability and safeguarding requirements are high. If vehicles are used beyond school peak periods, agencies would also need to determine whether community users or other local riders could improve fleet utilization without affecting student safety or service priority. Second, demand estimation is another area that would benefit from further validation. The present analysis supports the feasibility of the school-peak service concept and uses available stop-level student counts and bus ridership scenarios to identify candidate zones. This is appropriate for planning-level screening, but implementation should be supported by student and family surveys, discussions with school transportation staff, and pilot data on bookings, cancellations, vehicle occupancy, no-shows, travel-time reliability, and satisfaction. These data would help refine vehicle assignments, confirm whether students would use the service, and assess whether the modeled travel-time benefits are achieved under actual operating conditions.

8. Conclusion

This study examined whether a semi-flexible DRT service concept, when combined with fixed-route optimization, can improve high school commute accessibility in underserved and low-density areas of El Paso, Texas. The analysis used GIS, GTFS data, Google Maps Directions API, EPISD bus-route information, school attendance zones, and stop-level student counts to evaluate existing accessibility, identify low-demand stops, form DRT zones, and restructure affected fixed routes.

The planning results indicate potential reductions in modeled student travel time and changes in planned service coverage under the stated routing, demand, and vehicle-capacity assumptions. These findings represent modeled accessibility and operational performance rather than observed student outcomes or implemented service conditions. Although service area coverage was good, travel times for high school students on fixed-route transportation were also very high. This is largely because El Paso is characterized by its low population density, which makes traditional fixed-route transit networks expensive and ineffective due to comparably lower demand than that of cities with high population densities. The study demonstrated the potential for significant reductions in travel time for students and an expansion of the service area for a 30-minute commute through the suggested DRT network. The DRT network improved accessibility by reducing travel time, expanding the coverage area, and offering more transportation options for students. Furthermore, the study showed operational efficiency gains through a reduction in the number of active routes after the implementation of the DRT network and route optimization for EPISD. Specifically, the number of routes servicing Irvin, Chapin, and Bowie High Schools was reduced from 12 to 7. Various high schools affected by DRT network creation experienced benefits in different ways. Coronado and Franklin High Schools saw significant changes in travel times due to the DRT network implementation, with a difference of up to 27 minutes. Chapin and Irvin High Schools primarily benefited from route optimization following the creation of the DRT network. Notably, Bowie High School benefited from both the DRT network and route optimization, experiencing the biggest change in travel time average with a reduction of 10 minutes. It was also concluded that the addition of a DRT service can not only be implemented for students commuting to school during regular school operations, but service hours can be expanded for students who participate in extracurricular activities that require them to be on campus earlier or later than their classes. The flexibility of the DRT network allows students not to be limited by the scheduled fixed route transportation, which increases their access and ability to participate in extracurricular activities.

Although a comprehensive service analysis was conducted before DRT service design was suggested, some of the limitations of this study are as follows:

(1) It is important to note that although certain coverage areas extended further than the attendance zone of the corresponding school, the areas were cut to be limited to the boundaries of the attendance zone, assuming that students are only traveling within their attendance zone. With this in mind, this study does not consider students who attend a different school from the one assigned to their address. Therefore, their coverage needs are not being considered in this study.

(2) It is also necessary to point out that several routes for the EPISD network did not contain information on the number of students who could potentially use the network per stop. For this reason, these routes were omitted from the DRT network and route optimization analysis. Therefore, with the addition of the missing information, the DRT network and the optimization of the route will change.

(3) No interviews or surveys were conducted with students, families, school staff, district transportation officials, or transit providers.

Future research can broaden this scope by estimating operating-cost analysis, examining access to micromobility options such as bicycles and electric scooters and evaluating the potential of integrated networks of shared mobility systems for improved accessibility for students in underserved communities.

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