ILLINOIS CENTER FOR TRANSPORTATION

CIVIL ENGINEERING STUDIES
Illinois Center for Transportation Series No. 23-028
UILU-ENG-2023-2028
ISSN: 0197-9191

Investigating Statewide Transit Maintenance Needs in Illinois

Prepared By
Ethan Light
Shang Sai
Yanfeng Ouyang
Will O'Brien
Jesus Osorio
Yuhui Zhai
University of Illinois Urbana-Champaign

Research Report No. FHWA-ICT-23-021

A report of the findings of

ICT PROJECT R27-SP58
Investigating Statewide Transit Maintenance Needs

https://doi.org/10.36501/0197-9191/23-028

Illinois Center for Transportation

December 2023

TECHNICAL REPORT DOCUMENTATION PAGE

1. Report No. FHWA-ICT-23-021	**2. Government Accession No.** N/A	**3. Recipient's Catalog No.** N/A
4. Title and Subtitle Investigating Statewide Transit Maintenance Needs in Illinois		**5. Report Date** December 2023
		6. Performing Organization Code N/A
7. Authors Ethan Light, Shang Sai, Yanfeng Ouyang (https://orcid.org/0000-0002-5944-2044), Will O'Brien, Jesus Osorio, Yuhui Zhai		**8. Performing Organization Report No.** ICT-23-028 UILU-2023-2028
9. Performing Organization Name and Address Illinois Center for Transportation Department of Civil and Environmental Engineering University of Illinois at Urbana-Champaign 205 North Mathews Avenue, MC-250 Urbana, IL 61801		**10. Work Unit No.** N/A **11. Contract or Grant No.** R27-SP58
12. Sponsoring Agency Name and Address Illinois Department of Transportation (SPR) Bureau of Research 126 East Ash Street Springfield, IL 62704		**13. Type of Report and Period Covered** Final Report 4/1/23–12/31/23 **14. Sponsoring Agency Code**

15. Supplementary Notes
Conducted in cooperation with the U.S. Department of Transportation, Federal Highway Administration.
https://doi.org/10.36501/0197-9191/23-028

16. Abstract
This study's researchers investigated transit vehicle maintenance processes, maintenance needs, and potential opportunities associated with building additional bus maintenance facilities (e.g., regional maintenance centers) in Illinois. They collected information via three main tasks. First, they conducted a literature review to document practices on preventive and corrective transit vehicle maintenance processes and explored similar or comparable projects among peer states and regions. Second, they conducted a series of interviews with Illinois local transit agencies, nonprofit organizations, Illinois administrators, and peer states to identify common challenges and opportunities with fleet maintenance as well as to capture stakeholders' perspectives on state-sponsored maintenance service. Third, they conducted a preliminary data-driven model analysis to present a better understanding of Illinois' needs for regional maintenance centers and to illustrate how the Illinois Department of Transportation may systematically plan regional maintenance center locations and capacities to best serve unmet demand under a range of available budget values. This study's findings lay the foundation for more effective planning of a better network of regional maintenance centers to provide long-term benefits to IDOT and partner agencies by reducing vehicle down time, decreasing maintenance and towing costs, and allowing for greater tracking of maintenance techniques in coordination with similar agencies across Illinois.

17. Key Words Transit Fleet, Maintenance, Regional Maintenance Center, Preventive, Corrective, Inspection	**18. Distribution Statement** No restrictions. This document is available through the National Technical Information Service, Springfield, VA 22161.

19. Security Classif. (of this report) Unclassified	**20. Security Classif. (of this page)** Unclassified	**21. No. of Pages** 56 + appendices	**22. Price** N/A

Form DOT F 1700.7 (8-72) **Reproduction of completed page authorized**

ACKNOWLEDGMENT, DISCLAIMER, MANUFACTURERS' NAMES

This publication is based on the results of **ICT-R27-SP58: Investigating Statewide Transit Maintenance Needs**. ICT-R27-SP58 was conducted in cooperation with the Illinois Center for Transportation; the Illinois Department of Transportation; and the U.S. Department of Transportation, Federal Highway Administration.

Members of the Technical Review Panel (TRP) were the following:

- Charles Abraham, TRP Chair, Illinois Department of Transportation
- Zoe Keller, TRP Co-Chair, Illinois Department of Transportation
- Jack Cruikshank, TRP Co-Chair, Illinois Environmental Protection Agency
- Laura Calderon, Illinois Public Transportation Association
- Daniel Engelkes, Rockford Mass Transit District
- Tony Greep, Federal Transit Administration
- Edward Heflin, Rural Transit Assistance Center
- Michael Pietrowski, Shawnee Mass Transit District
- Ramona Pitts, Illinois Department of Transportation
- Spencer Sidwell, Sangamon Mass Transit District
- Betsy Tracy, Federal Highway Administration

EXECUTIVE SUMMARY

This study's researchers investigated transit vehicle maintenance processes, maintenance needs, and potential opportunities associated with building more bus maintenance facilities (e.g., regional maintenance centers) in Illinois. They collected information about how the Illinois Department of Transportation (IDOT) could better use capital and operating funding to support public transit agencies statewide with maintenance of transit vehicles in urban and rural areas.

This study's researchers conducted three main tasks. First, they conducted a literature review to document practices on preventive and corrective transit vehicle maintenance needs and processes as well as explored similar or comparable projects among peer states and regions. Second, they interviewed local transit agencies, nonprofit organizations, IDOT bureaus, and peer states to identify current issues with their transit vehicle maintenance needs and processes as well as capture stakeholders' perspectives on state-sponsored maintenance services. Third, they conducted a preliminary data-driven model analysis to present a better understanding of Illinois' needs for regional maintenance centers and illustrate how IDOT may systematically plan regional maintenance center locations and capacities to best serve unmet demand under a range of available budget values.

This study's researchers made the following key findings:

- Many rural agencies/nonprofit organizations have recognized that their aging fleets are a severe problem and anticipate acquiring electric or hydrogen fuel cell buses in the next five years. They worry about electric buses' limited range and reliability and about inadequate infrastructure and technician expertise to support these new vehicles.

- Roughly 97% of buses that the interviewed agencies own are internal combustion vehicles. Gasoline is the mainstream fuel for cutaway buses.

- A similar proportion of urban and rural agencies/nonprofit organizations follow the original manufacturer's maintenance guidelines. They use a wide variety of fleet management software.

- There have been severe supply-chain issues for vehicle parts.

- Most agencies/nonprofit organizations have performed all maintenance in-house or have outsourced only major repairs (e.g., on the engine/transmission) to local mechanics shops. They are generally open to outsourcing major repairs to regional maintenance centers.

- A little over half of the agencies/nonprofit organizations thought they had enough technicians but wanted them to have training on new technologies.

- About half of the agencies/nonprofit organizations were open to hosting regional maintenance centers. They believed that regional maintenance centers have the potential to

concentrate highly skilled technicians and alleviate statewide challenges with transitioning to alternative fuel vehicles.

- Most southern transit agencies were more self-sufficient than northern, eastern, or western agencies, given less competition for skilled technicians with local mechanic shops.

- Peer state DOTs typically did not directly support maintenance programs through regional maintenance centers or similar facilities but supported local agencies' maintenance efforts through grants.

This study's findings lay the foundation for more effective planning of a better regional maintenance center network, which in combination with additional efficiency processes surrounding maintenance overall, will provide long-term benefits to IDOT and partner agencies. It can reduce vehicle down time, decrease maintenance and towing costs, and allow for greater tracking of maintenance techniques in coordination with similar agencies across Illinois. This study's researchers have also conveyed findings from this study to the researchers on the ICT-IDOT study R27-SP57, "Investigating Statewide Alternative Fuel Technician Needs."

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

CHAPTER 1: INTRODUCTION

Fleet maintenance significantly affects public transit systems' reliability, safety, cost-effectiveness, and sustainability. It accounts for approximately 21% of a typical transit system's total operating expenses (Purdy & Wiegmann, 1987). Fleet maintenance is the second highest expense category, trailing only after vehicle operating costs (Bladikas & Papadimitriou, 1986).

For a few decades, fleet maintenance costs have increased 33% faster than vehicle operating costs and multiple times faster than general/administrative costs (Purdy & Wiegmann, 1987). In 2021 alone, fleet maintenance costs reportedly rose 5%–10% from the previous year due to inflationary pressures and supply-chain constraints (Antich, 2022).

Fleet maintenance activities must strike a suitable balance between preventive maintenance (including regular inspections) and corrective maintenance (or repairs). Preventive maintenance is performed according to certain schedules to identify potential hazards or early indications of vehicle failure. Agencies can then take proactive actions to avoid major failure from happening. They incur small costs in the early stage of a vehicle's life cycle but minimize the chance of having costly repairs especially in later stages of the vehicle's life cycle. Therefore, preventive maintenance is often cost-effective in the long-term. Corrective maintenance, on the other hand, is typically reactive (i.e., done after unexpected bus failure) and is usually quite expensive.

The high operating and capital costs, dwindling ridership, decreasing sources of funds, and pressures to improve customer service to remain competitive have challenged transit service providers, especially after the COVID-19 pandemic. These challenges are even more pronounced for rural transit agencies, partly given uncertainties in their operating environment, differences in fleet maintenance requirements, and lack of suitable mechanics and machinery in rural areas.

The trend toward using zero-emission buses (ZEBs) is also exacerbating fleet maintenance challenges. Traditionally, fixed-route transit services use larger diesel engine or hybrid buses, while paratransit services use smaller gasoline buses. In recent years, the rapid transition toward cleaner energy such as electricity and even hydrogen has accelerated. According to Dickens and Neff (2011), purchases of alternative fuel transit vehicles in the U.S. increased by 764% between 1996 and 2009, while the purchase of diesel- and gasoline-fueled transit vehicles decreased by 39%. In more recent years, the trend of electrifying public transit vehicles has drastically grown, with government policies explicitly encouraging and enforcing the use of alternative fuel vehicles through federally funded grants. The use of alternative fuel vehicles in public transportation adds more complexity to the already complicated challenges of maintaining transit vehicles.

The Illinois Department of Transportation (IDOT) provides capital and operating funding to more than 50 public transit agencies statewide, including transit vehicles, maintenance/administrative facilities, and daily operations funding for both urban and rural areas. It also purchases paratransit vehicles on behalf of nonprofit organizations providing transportation services to seniors and individuals with disabilities. Currently, some transit agencies (mainly those in urban areas) perform in-house maintenance, while others (especially those in rural areas or with smaller fleets) typically outsource

vehicle maintenance to local mechanic shops. The use of local mechanic shops often suffices for general vehicle maintenance but can be problematic for transit-specific needs, such as working on automatic doors, wheelchair lifts, and bus bodies. Local mechanics may not have the technical expertise necessary to properly and efficiently perform transit-specific maintenance, especially with newer types of alternative fuel vehicles. The lack of sufficient maintenance capability and capacity can lead to scenarios where transit vehicles have to be retired/parted out before their useful lives have been exhausted.

To improve access to maintenance opportunities, IDOT has designated certain maintenance facilities as regional maintenance centers. Any IDOT-supported transit agency or nonprofit organization can take their vehicles to these regional maintenance centers and pay for maintenance or repairs. Regional maintenance centers have transit-specific expertise and are more affordable than outsourcing to private shops since they charge parts at cost and labor at a fraction of the private shop rate. There were multiple regional maintenance centers across Illinois in the past, but the Rockford Mass Transit District and the Sangamon Mass Transit District currently operate a regional maintenance center.

Regional maintenance centers allow transit maintenance facilities and mechanics to perform repairs and maintenance on other agencies' transit vehicles. This resource-sharing approach to transit vehicle maintenance, if properly planned and executed, can notably reduce transit vehicle maintenance costs for all affected transit agencies. The customers of regional maintenance centers can benefit from lower vehicle maintenance costs and better-quality maintenance while transit service providers who run regional maintenance centers can reduce their maintenance facilities' idle times and increase their utilization rates, thus saving money.

Yet, IDOT and other Illinois transit agencies lack studies to comprehensively understand their transit vehicle maintenance processes, maintenance needs, and potential opportunities associated with additional regional maintenance centers. This study's researchers thus sought to conduct a literature review and interviews with Illinois transit agencies and nonprofit organizations that have partnered with IDOT's Office of Intermodal Project Implementation for transit funding. They interviewed current regional maintenance centers, the Illinois Public Transportation Association, the Rural Transit Assistance Center, Pace, and IDOT district personnel who have maintained IDOT-owned vehicles. This study has documented any unmet maintenance needs, available maintenance resource supply, and the extent to which additional regional maintenance centers could help the entire state.

This study's findings, with additional efficiency processes surrounding maintenance overall, should lay the foundation for more effective planning of a better regional maintenance center network. It should reduce vehicle down time, decrease maintenance and towing costs, and allow for greater tracking of maintenance techniques in coordination with similar agencies across the state. Moreover, this study's researchers have included maintenance labor training needs in this report that shall support a separate ICT-IDOT study, R27-SP57: Investigating Statewide Alternative Fuel Technician Needs.

The remainder of this report is organized as follows. Chapter 2 reviews the literature on transit fleet maintenance, regional maintenance centers, and similar practices in peer states. Chapter 3

summarizes the interviews and surveys with multiple stakeholders. Chapter 4 conducts a preliminary analysis on possible regional maintenance center investment scenarios based on the collected data. Chapter 5 provides recommendations.

CHAPTER 2: LITERATURE REVIEW

Under the Technical Review Panel's guidance, the research team conducted a brief literature review (i) to understand any documented practices on preventive and corrective transit vehicle maintenance needs and processes; (ii) to explore similar or comparable projects among peer states and regions across the United States (e.g., Texas) on planning and running regional maintenance centers; and (iii) to collect existing tools for analyzing the location, capacity, and pricing of regional maintenance centers. This information provides key support for future regional maintenance center planning in Illinois. The research team also reviewed all related research work that the Transit Cooperative Research Program and other state DOTs based on online databases. This section provides a summary of these findings.

STATE OF THE PRACTICE

Despite the importance of investigating possible ways of reducing transit fleet maintenance costs and avoiding duplication efforts through entities like the Transit Cooperative Research Program (NASEM, 2005), there has only been an increase in research on public transit vehicle maintenance in recent years.

In a review of the literature focusing on rural transportation vehicle maintenance, Ng et al. (2012) found that transit fleet management was a relatively new science, having over 54% of related studies published after 2001. They found that only 10% of the 169 articles reviewed were quantitative.

Ng et al. (2012) also concluded that similar maintenance practices for both rural and urban transit vehicles might be counterproductive for rural transit vehicles and required tailored optimization efforts for rural agencies. They also showed that the current state of practice with reference to fleet maintenance emphasizes performance measurements that include standard repair times, performance indicators, preventive maintenance, and maintenance quality standards.

Standard Repair Times

Transit agencies have used frameworks that researchers had made to develop or adopt standard repair times (SRTs) to measure their mechanics' productivity, given the wide array of equipment, union agreements, and fleets. They typically have developed time standards based on their historical information or by adopting SRTs from other agencies to suit their needs (Venezia, 2004). They time inspection or repair tasks as outlined in the original equipment manufacturer guidelines as a way to apply industrial engineering principles to develop time standards. They will likely use several mechanics of various skill levels and average their times for inspection or repair tasks to create a SRT (Centeno et al., 2005).

Other agencies have stopped using time standards and instead use training and quality as performance measures (Venezia, 2004). Larger agencies with more sophisticated equipment can more accurately monitor an employee's time, generating reports detailing time spent on specific tasks (Schiavone, 1997).

Performance Indicators

Agencies may use performance indicators to measure maintenance quality and are typically based on miles between road calls, total cost per mile, and labor cost per mile. Agencies might choose different performance indicators based on their methods of data collection, their ease of understanding and defining issues, and their acceptance by unions (Robert & Hoel, 1981). Venezia (2004) conducted a survey to determine how agencies monitor maintenance quality. Venezia found that agencies typically categorize road calls by fleet and defect. It is important, however, to acknowledge that indicators will change, given changing operating conditions (Venezia, 2004).

Preventive Maintenance

Transit agencies developed maintenance standards in the 1980s to reduce maintenance costs and improve vehicle safety. Preventive maintenance involves periodic inspections of vehicle components and systems to identify and fix potential issues before they cause the vehicle to break down. Christer et al. (1984) defined preventive maintenance as having two elements: a schedule of activity performed and frequency of application. The authors divided the scheduled maintenance into three service types with varying levels of maintenance intensities. This level of division has since become the standard practice for many agencies. Table 1 highlights some standard preventive maintenance service intervals.

Table 1. Standard Preventive Maintenance Service Intervals for Transit Vehicles (TxDOT, 2003)

Level	Interval (miles)	Items
A	3,000	• Change oil and filter • Inspect tires • Inspect electrical systems • Service fluid levels • Lubricate chassis and doors • Check A/C, hoses, fire extinguishers, belts, brakes, and lights
B	12,000	• Conduct all level A items • Change transmission fluid and filter • Check coolant, specific gravity, and pH
C	24,000	• Conduct all level A and B items • Change oil filter • Perform engine tune-up • Test engine compression • Replace air filter and drain • Refill differential lubricant
D	48,000	• Conduct all level A, B, and C items • Inspect and repack of wheel bearings • Inspect braking system

Bus manufacturers now provide preventive maintenance guidelines for their vehicles, but many agencies adjust these to suit local operating conditions. In a Transit Cooperative Research Program survey, 66% of agencies felt that extreme heat, cold, dust, and road salt necessitated modifying the manufacturer's guidelines. The literature review showed that there is no single best approach to preventive maintenance; each agency should tailor their approach to preventive maintenance based on their fleet profile, resources, and local operating and environmental conditions. Once a preventive maintenance program is established, agencies should revise it through examination of their corrective maintenance patterns (Schiavone et al., 2010).

The increased use of zero-emission buses has further complicated effective maintenance strategies. The most common zero-emission bus types—battery electric vehicles and hydrogen fuel cell vehicles—have fewer moving parts than diesel buses, which can extend maintenance intervals (Callaghan & Lynch, 2005; Deliali et al., 2021). However, parts and/or equipment and knowledgeable mechanics who can maintain these vehicles are lacking (Ng et al., 2012).

Though dated, Robert and Hoel (1981) is an early example of how researchers have determined the state of practice of preventive maintenance. These researchers surveyed transit agencies in Virginia to assess their maintenance capability and preventive maintenance intervals. They found that preventive maintenance did not constitute a large part of the agencies' maintenance work.

Schiavone et al. (2010) conducted an extensive survey to determine how different agencies establish preventive maintenance intervals and how they can improve them. They found that transit agencies used checklists with varying degrees of specificity, pass/fail criteria, and written job instructions when conducting preventive maintenance inspections. They also revealed that agencies sought greater sharing of preventive maintenance information by other agencies, additional capability to analyze failure trends, and improved preventive maintenance schedules by bus manufacturers. This desire for greater information sharing serves as a motivation for developing strategies that pool knowledge of fleet maintenance. Regional maintenance centers can potentially fulfill this desire since they can serve as knowledge hubs, especially for rural transit agencies (Beruvides et al., 2009).

REGIONAL MAINTENANCE CENTERS

The concept of a regional maintenance center is relatively new compared to other efforts to reduce maintenance costs and improve maintenance quality. IDOT first pursued regional maintenance centers in the 1990s after recognizing that outsourced maintenance was falling short of quality standards and local mechanic shops had little accountability. A few other states (such as Texas) also considered such ideas, but Illinois is currently the only state to operate regional maintenance centers, with Rockford Mass Transit District and Sangamon Mass Transit District hosting these facilities. Regional maintenance centers seek to have larger transit agencies with robust maintenance programs provide transit maintenance services to other agencies with IDOT-funded vehicles. This resource-sharing approach to urban and rural transit vehicle maintenance, if properly planned and executed, can notably reduce transit vehicle maintenance costs for all involved transit agencies. Agencies that utilize regional maintenance centers benefit from specialized technical expertise that may not be locally available, and the host agencies benefit from increased use of their facilities.

Research on regional maintenance centers' logistics and effectiveness is scarce, if nonexistent. The current extent of published work on regional maintenance centers are three studies that the Texas Department of Transportation (TxDOT) commissioned beginning in 2007. These studies focused on defining the concept of a regional maintenance center, specifying service requirements, and creating a framework for identifying potential regional maintenance center host facilities. According to Beruvides et al. (2009), a regional maintenance center should fulfill the following main functions:

- Provide preventive maintenance and repair major components
- Provide transit-specific maintenance and repair services that local mechanics cannot offer
- Provide service to transit-specific vehicles, including wheelchair lifts
- Educate rural agencies on technical transit topics

They concluded that regional maintenance centers, while feasible, must be optimally located to minimize coverage overlap. The third study, Beruvides et al. (2010) developed a site assessment instrument for determining a maintenance facility's ability to become a regional maintenance center. This instrument considered factors such as the facility's location, current maintenance practices, equipment, technician training, and documentation practices.

CHAPTER 3: INTERVIEWS AND QUERIES

The research team conducted a series of interviews to provide a complete picture of IDOT's current transit fleet maintenance practices, processes, needs, and resource availability. They interviewed major transit agencies and nonprofit organizations located outside of northeastern Illinois that have received IDOT support for public transportation.

The research team used these interviews to focus on identifying current issues with grantee needs and processes that have been used to regularly schedule transit maintenance and conduct unscheduled repair work. They included questions on ADA equipment maintenance, unmet maintenance needs, the extent to which additional regional maintenance centers could help, and service pricing levels.

To facilitate the interview process, this study's researchers prepared a questionnaire (please see Appendix A) and distributed it with interview invitations. The TRP co-chairs suggested 29 agencies/nonprofit organizations. This study's researchers interviewed 23 of them from June to August 2023, including Pace Suburban Bus representatives who handled vehicle maintenance. The researchers investigated areas where collaboration on vehicle maintenance could be beneficial.

Figure 1 shows all interviewed agencies, and Appendix B provides the detailed interview schedule. To protect the interviewed agencies' data confidentiality, the research team omitted their names in some sections of this report and replaced them with a system of alias names ranging from "Agency A" to "Agency W." Please note that the aliases were assigned in no particular order.

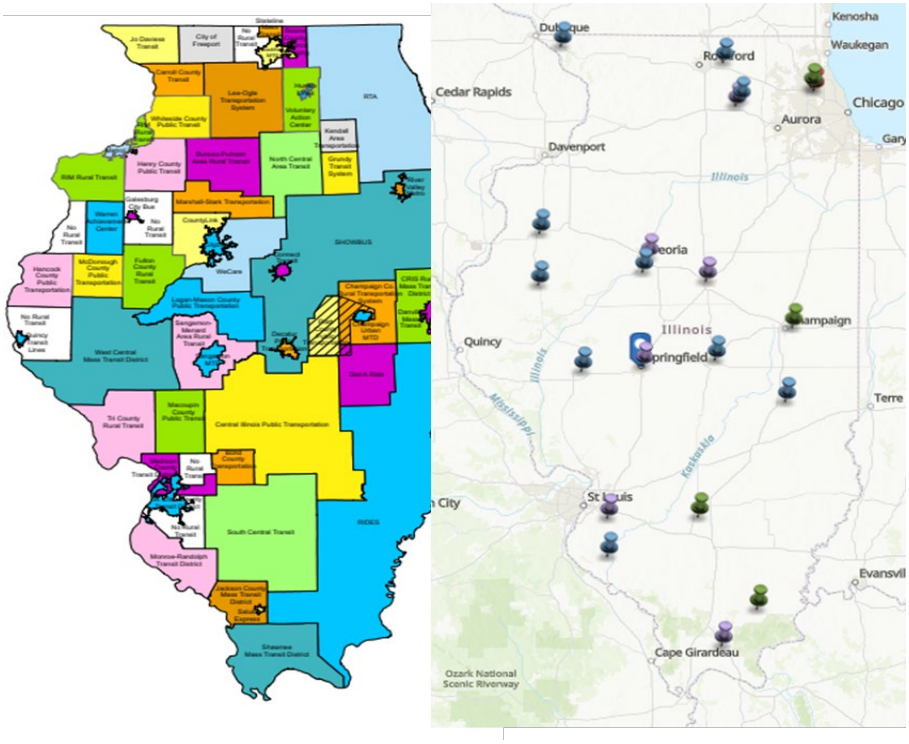


Figure 1. Map. Interviewed Illinois transit agencies and nonprofit organizations.

Meanwhile, the researchers conducted a second batch of interviews with representatives from IDOT's Bureau of Transit Operations and Consolidated Vehicle Procurement Section, the Illinois Department of Central Management Services, and Western Illinois University's Rural Transit Assistance Center. Each agency directly oversees a part of the fleet and regional maintenance center operations in Illinois. They sought to gauge these representatives' perspectives on ongoing transit maintenance challenges in Illinois as well as successes or lessons associated with existing regional maintenance centers.

Finally, the TRP Chairs helped send out information requests to all peer states, via the American Association of State Highway and Transportation Officials' (AASHTO) Transit Management Alert mailing list, to gauge their experiences on vehicle fleet maintenance questions. (Please see the email query in Appendix C.) The researchers received responses from eight states: California, Connecticut, Florida, Indiana, Michigan, Nevada, North Dakota, and South Dakota (shown in blue in Figure 2). They also organized two additional video conference interviews—one with colleagues from Caltrans, the California Air Resources Board, and the Humboldt Transit Authority to discuss their experiences and the other interview with the American Public Transportation Association.

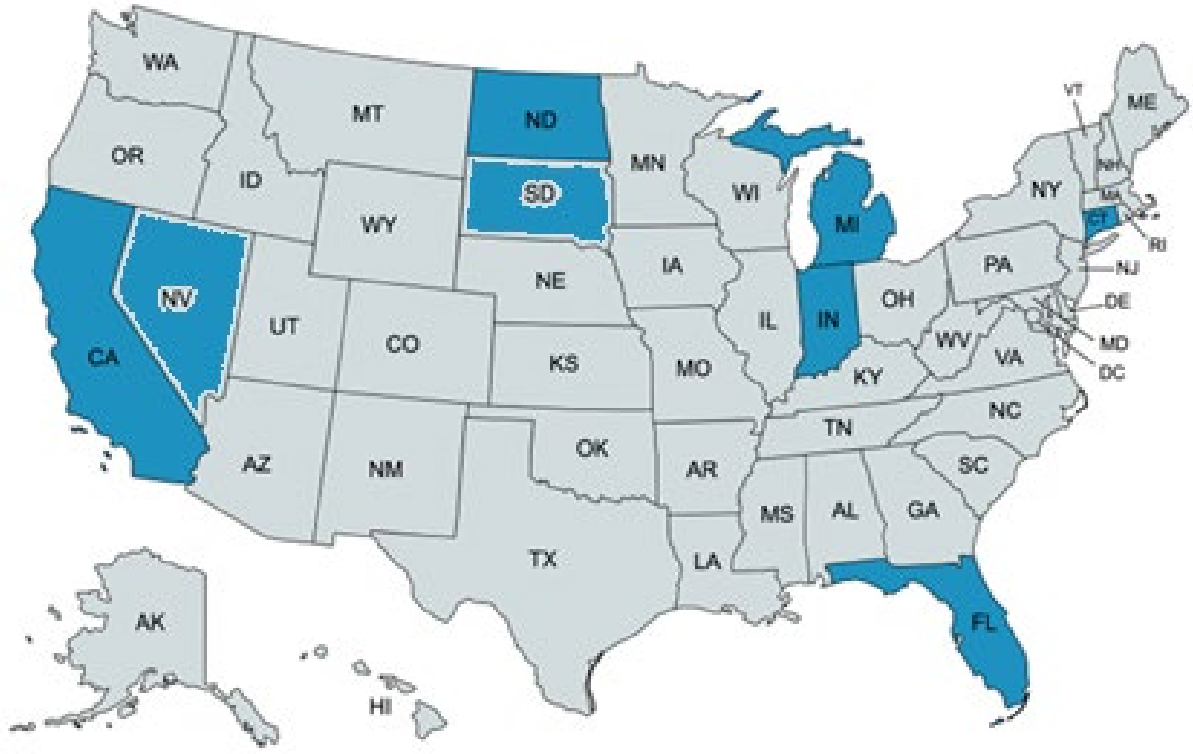


Figure 2. Map. The eight states that responded to the email query.

ILLINOIS LOCAL TRANSIT AGENCIES AND NONPROFIT ORGANIZATIONS

This section provides a summary of the interviews with the 23 transit agencies and nonprofit organizations on their fleet composition, maintenance practices, maintenance expenses, and available technician and facility resources.

Fleet Profiles

Many of the 23 agencies/nonprofit organizations were rural transit providers whose fleets largely consisted of cutaway buses for demand-responsive and paratransit operations. Figure 3 shows a histogram of their fleet sizes. Most respondents have a fleet size of fewer than 100 vehicles, with the lowest being only nine vehicles. Most urban transit agencies operate approximately 100 vehicles each, and the rural agencies operate approximately 20–50 vehicles each. The only clear exception is Pace, which operates more than 2,000 vehicles. The researchers did not get a chance to interview the Chicago Transit Authority (CTA), but historical records show that its fleet size is also much larger than all others.

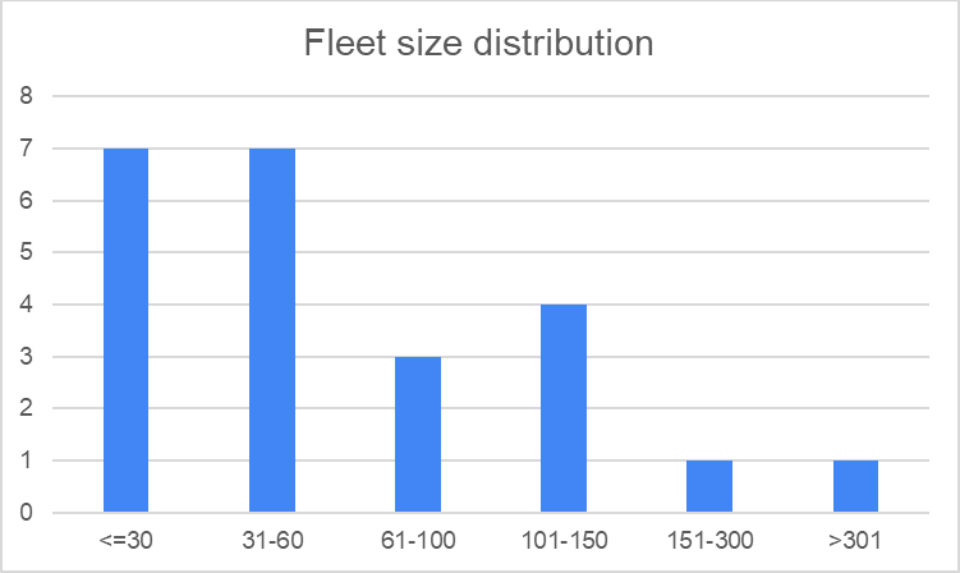


Figure 3. Histogram. Fleet size distribution among 23 Illinois transit agencies/nonprofit organizations.

Table 2 gives the current fleet size and operating condition at the agencies/nonprofit organizations. Approximately half of the 23 interviewed transit agencies/nonprofit organizations' total revenue vehicles were gas vehicles and approximately a quarter were diesel vehicles. The remaining quarter was a mix of hybrid (13%), compressed natural gas (2%), and electric vehicles (1.6%).

The Champaign-Urbana Mass Transit District (MTD) also operates two hydrogen buses, and the Bloomington-Normal Mass Transit District operates four propane buses. About two-thirds of the revenue vehicles serve on-demand/paratransit routes (64%), and the rest operate on fixed routes.

Some agencies that operate both heavy-duty buses and cutaway vehicles reported that the two types of vehicles are very different in terms of passenger capacity, operation methods, and maintenance costs. Heavy-duty buses are generally used for fixed urban lines with large passenger flow, while cutaway buses are more suitable for on-demand/complementary paratransit services and rural operations.

The average age of paratransit/demand-response vehicles among agencies that responded was 7.6 and 8.7 years, respectively. Rural agencies tended to have older paratransit/demand-responsive

vehicle fleets, with an average age of 8.46 years. Several rural agencies noted that their aging fleet was a problem. However, they had difficulty securing limited IDOT grants during the COVID-19 pandemic. They are now facing increasing operating and/or maintenance costs with their existing vehicles.

Rural agencies' perceived fleet condition is generally better than that of their urban counterparts. The average age of older paratransit/demand-responsive vehicle fleets was 5.93 years for urban agencies. Urban agencies perceived that their vehicles had an average IDOT condition rating of 3.5 out of 5 (where 1 indicates no defects, 2 indicates minor/limited defects, 3 indicates periodic defects, 4 indicates moderate deterioration and exceeds expected life, and 5 indicates excessive defects and needs complete replacement), whereas rural agencies perceived an average of 2.8.

Rural agencies typically spent less on maintenance per bus than their urban counterparts. Two urban agencies in particular, Agency F and Agency P, spent considerably more on maintenance per bus than other urban agencies. It is difficult to compare quantitatively the maintenance costs between agencies as they may have included different costs in their calculation. In addition, some agencies were unable to provide a detailed breakdown of repair costs upon request.

Table 2. Fleet Size and Condition of Transit Agencies/Nonprofit Organizations

Agency	Total Fleet Size	Avg. Fleet Age	Daily Miles	Average Condition	Overall Maintenance Cost	Fuel Type Breakdown
Agency A (Para)	26	8	1,200–1,500	Fair [interpreted as 3]	$75,000	Gas
Agency B (Para)	8	7.5	60	Good/fair [interpreted as 2.5]	$27,793.14	Gas
	1	7	67.9	Fair/poor [interpreted as 3.5]		Diesel
	1	7	264	Good/fair		Gas
Agency C (Fixed)	5	7	456	1	—	4 Gas, 1 Diesel
Agency C (Para)	4 (minivans) + 1 (bus)	8.2	—	—	—	—
Agency D (Para)	26	2003–2021	115	—	$176,928.55 (July 2022–June 2023 this fiscal year)	2 Diesel, 24 Gas
Agency E (Fixed)	62	8	2,442	2	—	34 Diesel, 22 Compressed Natural Gas, 6 Gasoline
Agency E (Para)	25	6	69.3	2	—	Gas
Agency F (Fixed)	25	7	200	4	$319,338.40	23 Diesel, 2 Hybrid
Agency F (Para)	7	10	475	5	$449,670.17	Gas
Agency G (Fixed)	8	6	—	4	—	—
Agency G (Para)	203				—	—
Agency H (Fixed)	18	13	100 miles per route	3	$250,000 (fixed + on-demand)	Diesel
Agency H (Para)	23	7	60-80 miles	3	$25,000	—
Agency I (Para)	15	11–12	367–433	3	—	Gas
Agency J (Fixed)	53	11	5,567	5	$1,754,000	46 Diesel, 4 Hybrid, 3 Electric
Agency J (Para)	48	6	3,000	4	Contracted to Transdev	Gas
Agency K (Fixed+Para)	145–150	—	—	—	—	—
Agency L (Fixed)	24	9.7	2300	4	$15,585	Diesel
Agency L (Para)	16	6	984	2	894.57	Gas
Agency M	42	7.07	141/vehicle	3	Parts and labor based on FY24 budget ~$790k	30 Diesel, 12 EV

Agency	Total Fleet Size	Avg. Fleet Age	Daily Miles	Average Condition	Overall Maintenance Cost	Fuel Type Breakdown
Agency M (Para)	19	4.58	83	3	Parts and labor based on FY24 budget ~$200k	4 Propane, 15 Gas
Agency N (Para)	26	7	200	3	$399,000	Gas
Agency O (Para)	76	9	—	Fair [interpreted as 3]	$214,000	58 Gas and 18 Diesel
Agency P (Fixed)	118	7	Varies	4	$3,126,120.34	116 Hybrid, 2 Hydrogen Fuel Cell
Agency P (Para)	14	5	Varies	3	$113,098.21	Gas
Agency Q (Para)	22 + 1 admin	10	1,700	4	$25,000	2 Diesel (14-pax medium duty, oldest 2). Others gas
Agency R (Fixed)	42	4.5	150/3k	4	—	11 Diesel, 31 Gas
Agency R (Para)	12	4	150	4	—	6 Diesel, 6 Gas
Agency S (Para)	25	8	400,000	3	—	22 Gas, 3 Diesel
Agency T (Fixed)	700	—	—	—	—	—
Agency T	400 Agency T owned + 840 Contractor owned + 300 vans in Vanpool	—	—	—	—	—
Agency U (Para)	—	—	—	—	—	—
Agency V (Para)	48	7–9	Depends, 35–200	Good condition [interpreted as 1]	$200,000	Most gasoline, 1 diesel
Agency W (Para)	140	—	8–9k for entire fleet (57–64 on average)	Fair [interpreted as 3]	$240,000	65% gasoline and 35% diesel

The use of electric and hydrogen fuel cell vehicles in public transportation has become a trend in recent years, but many agencies are skeptical about the associated challenges. Currently, only two of the 23 agencies/nonprofits own electric buses and one owns hydrogen fuel cell buses. However, nine agencies said they expect to operate electric or hydrogen buses within the next five years. The perceived challenges, especially for rural agencies, include high prices, limited ranges, and lack of technicians with relevant experience.

Table 3 lists the reported plan of additional vehicle acquisition expected in the next five years. Many agencies/nonprofit organizations expressed a strong interest in pursuing new fuel vehicles such as electric or hydrogen fuel cell buses. Most expect financial support from IDOT to allow such vehicle acquisitions.

Table 3. Future Plan on Fleet Acquisition in Five Years

Agency	Model	Fuel Type	Seat Capacity	Quantity	Source of Funding
Agency A (Para)	Ford Transit	Gas	12	10	IDOT
		Electric		2	
	Transit	Hydrogen		2	
	Chrysler Minivan	—	5–7	4	
Agency B	Dodge	Gas	6	2	Federal/State Grant
	Ford	Gas	14	15	Federal/State Grant
Agency C	—	—	—	—	—
Agency D	—	—	—	—	—
Agency E	35 ft	Hybrid	—	12	Not yet funded
		CNG	—	7	
Agency F	Gillig LF	Hybrid	—	5	Federal Transit Authority, IDOT
	Paratransit	Gas	12–14	4	FTA
Agency G	Super-medium duty	—	26	11	IDOT Consolidated Vehicle Procurement
	Medium duty	—	14	30	
	Minivan	—	6	2	
Agency H	35 ft heavy duty	Diesel	32	4 to 6	Rebuild Illinois, 5309 grant
	Medium-duty bus	Gas	14	1	Rebuild Illinois
Agency H	—	—	—	3	IDOT Consolidated Vehicle Procurement
Agency I	—	—	—	7	IDOT Consolidated Vehicle Procurement, 0-Low emission grant (IDOT to Federal)
Agency J	Gillig	Diesel	32	10	Rebuild Illinois
	—	Electric	32	24	—
Agency K	—	—	—	—	—

Agency	Model	Fuel Type	Seat Capacity	Quantity	Source of Funding
Agency L	Ford 450 / Starcraft	Gas	14	7	IDOT Consolidated Vehicle Procurement / FTA 5307
	Dodge Caravan	Gas	7	3	
	Gillig LF	Diesel	32	9	IDOT Rebuild Illinois / FTA 5339
	VMC Optimal	Electric	13	2	FTA 5339
Agency M	Proterra 40 ft	Electric	—	10	Already procured
Agency N	Ford E450 Elk heart Paratransit Van	Gas	14	3	Rebuild Illinois
Agency O	Ford	Gas	14	30	IDOT Consolidated Vehicle Procurement
Agency P	60 ft	Diesel-electric hybrid	—	4	Federal & local
	40 ft	Hydrogen fuel cell	—	10	
	40 ft	Diesel-electric hybrid	—	20	
	Paratransit vans, E-450	Gas	14	3	Local
	Paratransit vans	Electric	—	2	IDOT Consolidated Vehicle Procurement
Agency Q	—	Electric	14	2	FTA
	—	Gas	14	4+	IDOT
Agency R	Ford	Gas	12	5	Local
	Chevy	Gas	12	5	Local
Agency S	—	Gas	12 to 14	6 for Dekalb, 4 for Kendall	IDOT Consolidated Vehicle Procurement
Agency T	—	EV	—	1	—
Agency U (Para)	Depends on CVP + Federal & State grants. Downstate special grants. Fleet is top priority	—	—	—	—
Agency V	—	Electric	—	3	—
	Ford, Dodge, Chevy	Gas	—	17	
Agency W	—	—	14–28	13	IDOT
	—	Electric	14–28	3	

Inspection and Maintenance Practices

Generally, maintenance practices vary drastically among the interviewed agencies/nonprofit organizations. These differences depend upon their fleet composition, operating methods, and vehicle conditions. Table 4 summarizes these current practices.

Even for the same vehicle type operated by the same agency, inspection and maintenance practices can vary based on vehicle age. For example, some agencies mentioned that they have conducted more frequent inspections on vehicles that have reached a certain age or mileage threshold.

Most agencies tended to use mileage intervals to determine preventive maintenance inspections. For agencies reporting exact intervals, 3,000, 5,000, and 6,000 miles were the most common intervals for their level A inspections of almost all vehicle parts.

While most agencies reported costs for their A, B, C, and D levels of preventive maintenance, they did not specify their intervals for the less frequent levels (B–D inspections). Rather, 14 agencies reported that the manufacturer's recommended intervals were sufficient for their operations; others adjusted their intervals using those that IDOT recommended or more frequent intervals for specific parts. Five of the six urban agencies/nonprofit organizations, and nine of the twelve rural ones reported that they followed the suggestions of the original equipment manufacturer (OEM). Such similarity across rural and urban agencies might be due to the offset between (i) the rougher conditions in rural areas, which necessitate more frequent inspections, and (ii) limited resources available in rural areas to perform inspections.

Some agencies had special schedules for specific parts of their vehicles such as axles or engines. Only Agencies F and H reported using time intervals for preventive maintenance (monthly and 90 days, respectively). They also reported that their drivers conducted daily or weekly visual inspections of the vehicle bodies, although these visual inspections are not considered to be part of the preventive maintenance inspections.

The extent and types of maintenance activities outsourced to local mechanics shops vary drastically across agencies/nonprofit organizations. Agencies B, D, K, and V, outsource all fleet maintenance to local mechanics shops. This was inferred for Agency K since they do not employ technicians. Agencies I, L, N, O, S, and T only outsource major repair jobs such as engine/transmission, body work, or wheel and brake repairs. Agency I outsources maintenance depending on the best quote from local mechanics shops.

While the OEMs recommend preventive maintenance intervals in their manuals, many agencies/nonprofit organizations have practiced more frequent inspections. During the interviews, 57.7% of respondents reported that they did not exactly follow these OEM recommendations. Their practices ranged from full compliance with IDOT or contractor suggestions, to simply adding one or two additional maintenance routines to the OEM recommendations. One possible explanation for this high percentage of extra inspections is that many interviewed agencies/nonprofit organizations operate in rural or rural-urban areas. Higher service mileage, longer operating hours, poorer road conditions, and extra reliability requirements can all lead to a more proactive maintenance strategy than the OEM suggestions.

The researchers also asked the agencies/nonprofit organizations to report their use of fleet management software. Most respondents use existing commercial software to manage their fleets, and two agencies who do not currently do so have plans to implement it. The software options range from simple spreadsheet software like Excel to professional fleet management software such as FleetNet, FleetMate, and EcoLane. The largest agency interviewed, Pace, has multiple software systems, because multiple contractors who use different software systems each operate a significant portion of its fleet.

Table 4. Current Maintenance Practice

Agency	Manufacturer's manual enough?	What metric is used to schedule preventive maintenance?	Any software used?
Agency A	N	Miles and other (maintenance before the mileage reached)	CTS/TripMaster, moving to RTA
Agency B	Y	Miles	Spreadsheet, driver check mileage, also use EcoLane (dispatch software)
Agency C	N, just Automotive Wolf & IDOT suggested preventive maintenance schedule, change oil more often than manual suggestion	Other	Automotive Wolf (tracks monthly mileage, suggests preventive maintenance, cheap)
Agency D	N, use IDOT suggested maintenance schedule	Other	Spreadsheet
Agency E	Y	Miles	Fleetnet
Agency F	Y, adjust if needed	Miles and age	EAM Trapeze
Agency G	—	Miles	ManagerPlus
Agency H	Y	DAYS (p.m. maintenance, 90-day) MILES (oil, 5000 for oil change gasoline [other 100,000], 6000 for diesel)	FleetMate
Agency I	Y	Miles	EcoLane
Agency J	Y	Miles	FleetNet
Agency K	Y	—	Enterprise maintenance plan (Toyota, IDOT, etc.)
Agency L	Y	Miles	RTA
Agency M	Y, occasionally more frequent (3k miles inspection)	Miles	Fleetnet
Agency N	Y	Miles	TripMaster (Installed in past year)
Agency O	Y	Miles	CTS, RTA and Microsoft Excel
Agency P	Y	Miles	FleetNet

Agency	Manufacturer's manual enough?	What metric is used to schedule preventive maintenance?	Any software used?
Agency Q	Use manufacturer manual as a starting point. Depending on severe vs. light-duty use. 7.5 k -> 5k mile thresholds (easier for driver to keep track of and also take care of rural working conditions (dusty, gravel roads). Thorough and frequent inspections whenever a vehicle is in the garage.	Miles	Excel
Agency R	—	Miles	M-5, EAM
Agency S	Y	Miles	FleetMate
Agency T	N, Go above manufacturer's recommendations. Fixed-route larger buses, every 3k miles (each inspection varies in scope). Paratransit is based on 3k miles or 30 days.	Hours + Miles	Oracle EAM (by Agency T itself), and multiple other system(s)
Agency U	Y, deviate for buses	Miles	Transitioning into in-house software
Agency V	Y. For vehicles 5 years and older, shortened oil change mileage significantly	Miles	Not yet. New software expected in summer 2023
Agency W	Y, but also have additional maintenance	Miles	No, have funding but have not used software.

Table 5 shows the current outsourcing "location" for each bus system's preventive maintenance—either in-house (including maintenance that a contracted public transit operator performed) or outside company/shop(s).

Table 5. Preventive Maintenance Intervals and Outsourcing Practice

Agency	Engine and powertrain (exhaust, hydraulics, driveline)	Drive axle (wheels, brakes, suspension, steering)	Body and chassis (wheelchair ramp/lift)	Others (electrical, AC, air system)
Agency A	In-house	In-house	In-house	In-house
Agency B	Outsourced	Outsourced	Outsourced	Outsourced
Agency C	In-house at IDOT schedule	In-house at IDOT schedule	In-house at IDOT schedule	In-house at IDOT schedule
Agency D	Outsourced	Outsourced	Outsourced	Outsourced
Agency E	In-house at 6K miles (main fleet) or 4.5K miles (paratransit)	In-house	Contract out some body work (currently building a facility, should be all in house by the end of 2023)	In-house
Agency F	In-house, monthly	In-house, axle every 100,000 miles, everything else monthly	In-house, monthly	In-house, monthly
Agency G	In-house, 6K miles	In-house, 6K miles	In-house, 6K miles	In-house, 6K miles
Agency H	In-house, 90 days	In-house, 90 days	In-house, 90 days	In-house, 90 days
Agency I	—	—	Depends on severity and quote, no set shops	—
Agency J	In-house, 6K miles	In-house, 6K miles or weekly	In-house, 6K miles or daily	In-house, 6K miles or software tracker
Agency K	—	—	—	—
Agency L	In-house for preventive maintenance, 6K miles; outsourced for repairs	In-house for preventive maintenance, 6K miles; outsourced for repairs	In-house for preventive maintenance, 6K miles; outsourced for repairs	In-house for preventive maintenance, 6K miles; outsourced for repairs
Agency M	In-house, 3K miles, except for major engine/transmission repairs	In-house, 3K miles	In-house, 3K miles, except accident repair on body and chassis outsourced: outsourced	In-house, 3K miles

Agency	Engine and powertrain (exhaust, hydraulics, driveline)	Drive axle (wheels, brakes, suspension, steering)	Body and chassis (wheelchair ramp/lift)	Others (electrical, AC, air system)
Agency N	In-house, 4K miles, except for major jobs contracted locally	In-house, 4K miles or driver checks	In-house, 4K miles or driver checks	In-house, 4K miles or driver checks
Agency O	In-house, 5K miles (fixed route) and 15K miles (paratransit)	In-house, 5K miles	In-house, 5K miles (fixed route) and 15K miles (paratransit)	In-house, 5K miles (fixed route) and 15K miles (paratransit)
Agency P	In-house, 3K miles (special-fuel bus, 2013 and older), 6K miles (regular), 5K miles (paratransit)	In-house, 6K miles (regular), 5K miles (paratransit)	In-house, 6K miles (regular), 5K miles (paratransit)	In-house, 6K miles (regular), 5K miles (paratransit)
Agency Q	In-house, 5K miles	In-house, 5K miles	In-house, 5K miles	In-house, 5K miles
Agency R	In-house, 5K miles (fixed route) and 25K miles (paratransit)	In-house	In-house	In-house
Agency S	In-house, 5K miles, except for some diesel engine work	In-house, 5K miles, except for wheels & brakes on bigger buses	In-house, 5K miles	In-house, 5K miles
Agency T	In-house, 3K miles, except for engine replacement	In-house, 3K miles	In-house, 3K miles	In-house, 3K miles
Agency U	In-house	In-house	In-house	In-house
Agency V	Twice a year, every 25K miles	Every oil change, or 3–5K miles	Body: daily/every shift	AC: daily Electrical: daily Others: once a year
	Outsourced to 3 different local shops; staff is being trained	Outsourced to 3 different local shops; staff is being trained	Outsourced to 3 different local shops; staff is being trained	Outsourced to 3 different local shops; staff is being trained
Agency W	—	—	—	—

The variation across these agencies and nonprofit organizations' maintenance strategies may be a factor for considering when planning regional maintenance centers. Many agencies/nonprofit organizations strongly support centralizing fleet management software and information provisions (e.g., sending reminders about scheduled maintenance). The management software must accommodate all of their preferred strategies since regional maintenance centers simultaneously serve multiple agencies/nonprofit organizations.

Resources and Capabilities

To capture the interviewed agencies/nonprofit organizations' maintenance capabilities, the study researchers asked them to report on their number of facilities, technician staffing levels, and types of maintenance performed in-house. They also asked them to describe their ADA maintenance capabilities and their methods of training technicians. The study researchers sought to identify agencies that are largely self-sufficient and may be good candidates for hosting new regional maintenance centers. The response from these agencies/nonprofit organizations also provided valuable information pertaining to what types of maintenance they would outsource to a regional maintenance center.

Despite considerable differences in their equipment maintenance and scale, most of them reported operating at least one maintenance facility and employing at least two technicians. The only exceptions were Agencies B, D, and L. Agencies D and L did not have their own maintenance facilities, so they outsourced all maintenance services. Figure 4 shows the distribution of the number of maintenance facilities which the interviewed transit agencies/nonprofit organizations owned. Many of them operated only one facility, while larger mass transit districts tended to operate more than one facility.

The researchers also asked these transit agencies/nonprofit organizations to report the number of full-time and part-time technicians. It was most common for them to either employ one or two technicians (7 agencies) or more than 14 technicians (6 agencies). Transit agencies/nonprofit organizations that operated more than one facility always employed 14 or more technicians. Only five agencies/nonprofit organizations employed part-time technicians. Agencies K and Q employed no full-time technicians. Figure 5 shows the distribution of the number of technicians that these agencies employed (either full-time or part-time).

Three of the six agencies that employed more than 14 technicians were rural. Two of these rural agencies serve multiple counties and have maintenance depots in multiple counties. The remaining three agencies with over 10 technicians operate in small or large urban environments and offer fixed and demand-responsive/paratransit services. The Springfield Mass Transit District already has a regional maintenance center and operates a large 16-bay maintenance garage with separate paint and body shops nearby.

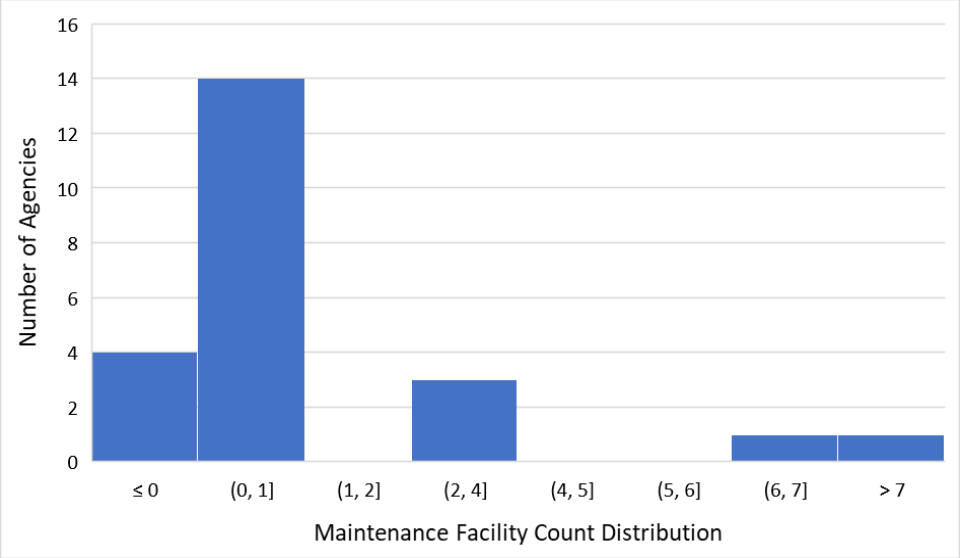


Figure 4. Histogram. Distribution of the number of maintenance facilities owned by 23 respondents.

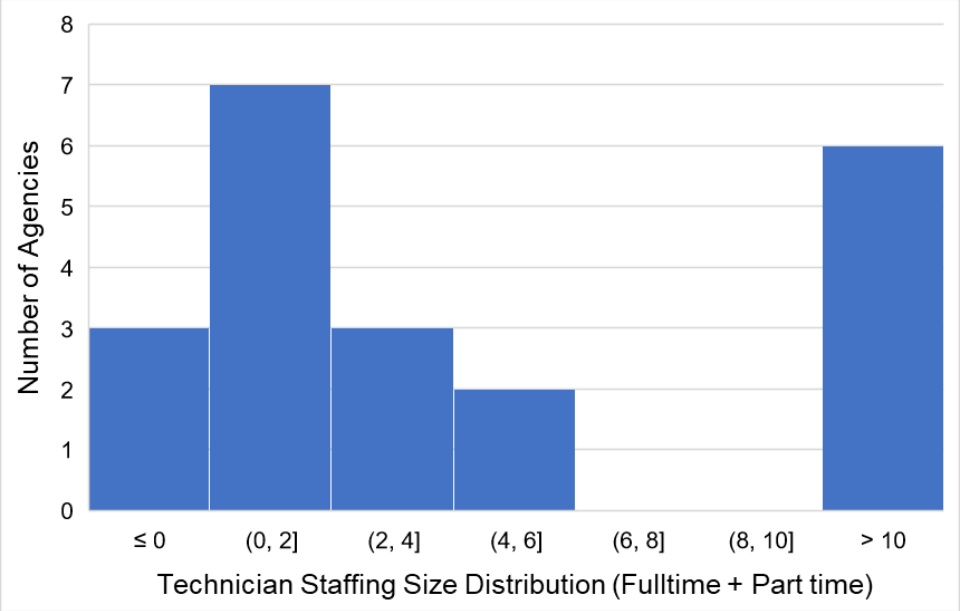


Figure 5. Histogram. Distribution of technician staffing levels among 21 respondents.

The researchers asked agencies about their efforts to coordinate vehicle maintenance with non-transit agencies. Only five agencies—four rural and one urban—reported conducting such practices, which suggests that it is not a common practice.

When asked about their ADA maintenance capabilities, seven agencies reported employing ADA-certified technicians. They reported that technicians have received training from a variety of sources, primarily manufacturers, but also from regional maintenance centers and ADA-certificated organizations. Please note that some agencies did not employ ADA-certificated technicians. However, they included maintaining ADA equipment maintenance as part of their job training.

Whether the current number of technicians is sufficient for smooth operations is extremely important to the general condition of an agency's fleet. Eleven out of the eighteen agencies/nonprofit agencies believed that they had a sufficient number of technicians to support their maintenance operations. However, some agencies pointed out that COVID's strain on the workforce will be felt across the nation for a long time. One agency reported that although current technician levels are sufficient, they would be willing to hire more people.

A potentially useful metric for estimating the workload of an agency's technicians is the ratio of revenue vehicles to technicians, as shown in Figure 6. With an overall median of approximately 12 revenue vehicles per technician, five of the seven agencies who reported a technician shortage fell to the right of the median. The outlier shown in Figure 6, reported being understaffed with only one technician—yielding a vehicle/technician ratio of thirty-seven. This agency also reported renting out two other maintenance facilities, which could be added to their technician count. The other two agencies with high vehicle/technician ratios were Agencies S and W. Agency S reported sufficient technician counts, and Agency W stated that they were still in the process of hiring.

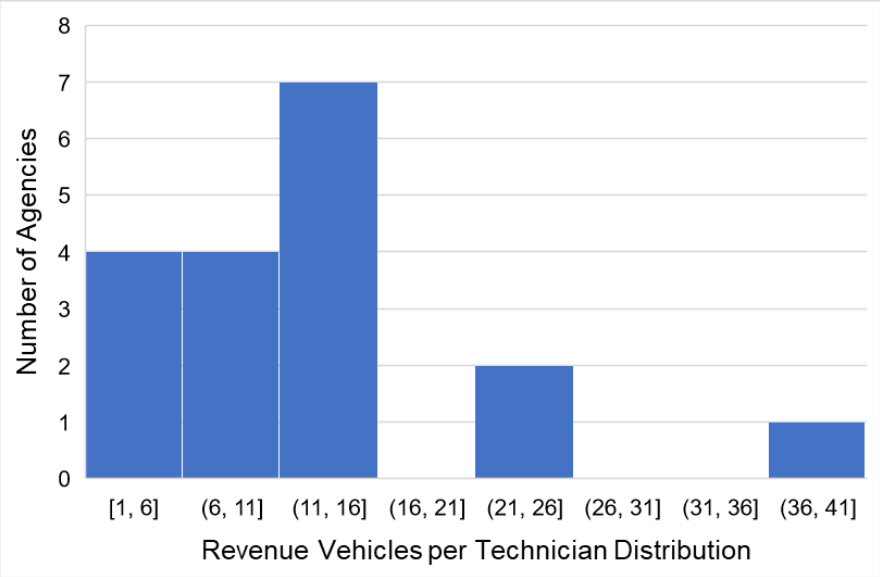


Figure 6. Histogram. Distribution of revenue vehicles per technician among 18 respondents.

Differences in facilities and equipment maintenance will inevitably affect the types and levels of repairs and inspections that agencies can complete. Twenty agencies reported completing preventive maintenance and minor repairs on their own. However, only 11 agencies indicated completing major repairs and body/chassis repairs at their facilities. Agencies C, M, and N reported only completing one of these two advanced repairs.

Although Agency K did not have its own facility, they still reported conducting preventive maintenance; another agency manages Agency K, so it is possible that Agency K uses their facilities. Generally, the larger transit agencies completed all types of repairs and preventive maintenance in-house. Smaller agencies such as Agencies A, H, Q, and S also performed these services despite employing four or fewer technicians. Table 6 provides a complete summary of information on technicians.

Table 6. Technician Information

Agency	# full-time technicians	# part-time technicians	Enough technicians?	ADA certificated?	How are techs trained to maintain ADA equipment
Agency A	1	1	Yes, will need more after merging	Yes	Rockford Regional Maintenance Center
Agency B	0	0	—	No	Local mechanic shop is certified to inspect, maintain, and repair ADA equipment
Agency C	3	0	Yes	—	They aren't
Agency D	0	0	—	0	—
Agency E	18	0	Yes	Yes	Trained by manufacturer, new technicians trained by ADA certificated technician
Agency F	2	0	No	Yes	Follow Original Equipment Manufacturer Manual
Agency G	15–20	0	No, have to hire	NO	—
Agency H	3	1	Yes	—	—
Agency I	1	0	Yes	No	—
Agency J	14	0	Yes	No	Job training and manual
Agency K	—	Some transportation assistants to do general checks	—	—	—
Agency L	3	—	N	YES, 2	—
Agency M	5	0	N, would like to have 3 more for the 80 vehicles	No	In-house training with manual and manufacturer-provided training

Agency	# full-time technicians	# part-time technicians	Enough technicians?	ADA certificated?	How are techs trained to maintain ADA equipment
Agency N	1	1	Yes	No	Follow manuals (DVD), also local company that is ADA-certified for other work
Agency O	44	0	—	—	Attended wheelchair lift training at regional maintenance centers
Agency P	19 mechanical technicians, 4 body shop technicians. 2 mechanical technician apprentices/ interns **when fully staffed	—	Yes, as more zero-emission technologies are introduced, will likely need more technicians. Current schedule is a 24-hour schedule	No	Job training from foreman
Agency Q	—	2, dual role mechanic vs. manager	N	Y,1	Manufacturer training and on the job training
Agency R	—	—	—	—	By Bi-State Development/Metro Training Department
Agency S	2	0	Y	Y,2	Training from Braun (ADA lift manufacturer)
Agency T	300	0	Y, would like new staff if possible but sufficient as of now	Y	Part of standard training
Agency U	1 (2.5 needed for full maintenance)	—	N	No	Used to be Braun (stopped doing it, shifted to online course)
Agency V	0	0	Y, happy with the current situation	No	—
Agency W	6 and 1 supervisor	—	No, still hiring	No	—

Maintenance Expenses

This study's researchers asked in the interviews about the transit/nonprofit organizations' maintenance costs, especially preventive maintenance costs. They asked them to provide the proportion of preventive maintenance costs in total maintenance costs and the costs of three levels of preventive maintenance as well as acceptable increases or expected decreases. The three levels were: Level A (6,000 miles), Level B (24,000 miles), and Level C (Infrequent).

Please note that not all agencies used this type of preventive maintenance classification. Some agencies divided preventive maintenance into four categories, while others implemented different maintenance intervals or different preventive maintenance definitions. Table 7 gives an overview of the annual expenses at various levels (per vehicle).

Table 7. Maintenance Cost Per Inspection and Flexibility

Agency	Preventive maintenance cost as % of maintenance cost	Level A (current cost, upper limit)	Level B (current cost, upper limit)	Level C (current cost, upper limit)	Level D (current cost, upper limit)	Notes
Agency A	40%	$60, $75	$120, $150	$150, $188	$300, $375	—
Agency B	—	—	—	—	—	—
Agency C	—	—	—	—	—	—
Agency D	100%	$1482.17	50k miles & 70k miles are major checks	—	—	120%
Agency E	Unknown	Fixed route: $870. Para: $145 (4,500 mi).	—	—	—	—
Agency F	40%	$400	$550	$750	—	Already at the high-end, maybe +/- 10%
Agency G	98%	—	—	—	—	Not enough data
Agency H	2%	—	—	—	—	Not enough data
Agency I	—	—	—	—	—	—
Agency J	—	$181.72	$527.68	$181.72	$527.68	—

Agency	Preventive maintenance cost as % of maintenance cost	Level A (current cost, upper limit)	Level B (current cost, upper limit)	Level C (current cost, upper limit)	Level D (current cost, upper limit)	Notes
Agency K		$150–180, 0%	$300, 0%	450–500, 0%	$1,450–1,500, 0%	No flexibility
Agency L	10%	6k miles, $560.45, 190%	6k miles, $620.24, 175%	18k miles, $754.59, 205%	—	—
Agency L (Para)	—	5k miles, $303,94, 300%	15k miles, $330.67, 250%	30k miles, $449.7, 115%	—	—
Agency M	—	$210 (parts) + $150 (labor), 10%	$410 + $290, 10%	150k miles, $1708 + $801, 10%	—	—
Agency N	70%	—	—	—	—	—
Agency O	45%	$82	$120	$200	—	Upper limit not given
Agency P	—	—	—	—	—	—
Agency Q	15/25	5k miles, 80% of 15K, FY23 budgeted $40k	Seasonal, 10% of 15K, FY23 budgeted $25k	10%, FY23, budgeted$50K	—	—
Agency R	15.00%	5K miles, $157.02	25K miles, $246.3	—	—	—
Agency S	70--75k	$250, $300	$1,000, $1,200	$1,000, $1,200	—	—
Agency T	—	—	—	—	—	—
Agency U	10% of budget	—	—	—	—	(excluding wages)
Agency V	80.00%	—	—	—	—	—
Agency W	60%	100,160	200,250	300,350		

Most agencies could not give an accurate estimate for an acceptable increase in the cost of each maintenance level. Of the seven agencies that provided an estimate, Agency K indicated that it could not spend more than it already does. For the remaining agencies, most can tolerate a 10%–20% spending increase.

Willingness to Host a Regional Maintenance Center

This study's focus is on the feasibility of establishing more regional maintenance centers, so the researchers asked about each agency's attitudes toward hosting a regional maintenance center or outsourcing maintenance to a regional maintenance center.

Of the 23 interviewees, three did not give clear answers, and one is already hosting a regional maintenance center. Of the remaining 19 respondents, 10 agencies expressed an interest in becoming a regional maintenance center, one claimed that the decision would depend on regional maintenance center requirements, and eight showed limited interest. One of these eight agencies noted that their office's successor might become interested, but at least for now they were not interested in becoming a regional maintenance center.

Of the 10 interested agencies, four said they would upgrade their existing facilities to a regional maintenance center, while three said that they would need to build new facilities. One agency stated they would need to expand existing facilities and build new facilities.

The cost and risks associated with building new facilities primarily deters those agencies that are not interested in becoming regional maintenance centers. One agency stated that they would be potentially interested if IDOT provided them with equipment and helped them hire more technicians. However, it is infeasible for now since their maintenance resources are at capacity. Another small agency reported they could not host a regional maintenance center given the lack of garage facilities. Similarly, another small agency that has a mechanical shop stated that it is too small for a regional maintenance center.

Eleven agencies out of 23 expressed their willingness to outsource repairs to a regional maintenance center, but regional maintenance centers are not usually their first option. Only Agencies B and D, which do not have their own facilities, were willing to turn everything over to a regional maintenance center. All other agencies would do preventive maintenance or minor repairs on their own and only outsource to a regional maintenance center for (i) major repairs/body or chassis jobs or (ii) issues that dealers now need to handle. Some agencies noted that their work with a regional maintenance center will not be regular, but rather based on occasional vehicle breakdowns. Agency B's comments may explain their cost-driven logic: "[We'll leave] anything to a regional maintenance center as long as it's cheaper [than their own garages]."

Competitive pricing, therefore, will be one of the key factors for a regional maintenance center's success. However, pricing is not the only factor. Even those interviewees who support regional maintenance centers worry about transportation: How long will the vehicles be on the road? How should they adjust their operating schedules when vehicles are being maintained, and who will pay for towing? Regional maintenance centers have to overcome these disadvantages compared to in-house maintenance or leaving the vehicles to local third-party shops.

One agency highlighted regional maintenance centers' impacts on local businesses. It helps local businesses and jobs if a local garage handles fleet repairs, which this agency sees as giving back to the community. While no other agencies/nonprofit organizations raised this point of view, it points out the need for a balance between efficiency from regional maintenance centers and economic equity for the local industry/community, especially in rural areas.

Table 8. Agency and Nonprofit Organizations' Views on Hosting or Outsourcing to Regional Maintenance Centers

Agency	Willing to host a regional maintenance center?	If yes, expand old facility or having new ones?	If no, why?	Willing to outsource to a regional maintenance center?	Type of maintenance you might outsource?	If no, why?
Agency A	Y	Expansion, already applied for funding	—	N	Anything to dealership	Mechanic on site
Agency B	N	—	No building	Y	Everything if cheaper	—
Agency C	N	—	Too small of a shop	N	Not on a regular, contrast basis, only for items that are not capable for in-house fixing	—
Agency D	Y	—	—	Y	All types	—
Agency E	—	Already a regional maintenance center	—	—	—	—
Agency F	Y	New, currently working on a master plan. Procurement of real estate in 2021 provides the land needed to build a regional maintenance center facility				
Agency G	—	Depends on what is required	—	N	—	—
Agency H	Y	Expansion	—		—	—
Agency I	Y	—	—	Y	—	Transfer of administration; currently (changing personnel)

Agency	Willing to host a regional maintenance center?	If yes, expand old facility or having new ones?	If no, why?	Willing to outsource to a regional maintenance center?	Type of maintenance you might outsource?	If no, why?
Agency J	N	—	In process of construction of new facility	Y	Major structural repairs and full rehabilitation of buses and paratransit vehicles	—
Agency K		—	—	Y	IDOT (all non-in-house work) *If regional maintenance center could provide warranty work, then yes to the non-IDOT fleet	—
Agency L	N	—	—	Y	Body and chassis work, major component repair or replacement	—
Agency L(Para)	N	—	Lack of staff, and space availability. Already at capacity. If IDOT is able to provide funding for staff/space /facility. Willing to discuss	Y	Larger repairs as necessary until staffing levels are sufficient. Have been subletting engine and transmission repairs to local Cummins and CIT locations while shorthanded.	—

Agency	Willing to host a regional maintenance center?	If yes, expand old facility or having new ones?	If no, why?	Willing to outsource to a regional maintenance center?	Type of maintenance you might outsource?	If no, why?
Agency M	N	—	—	N	—	(already cost-effective in-house)
Agency N	Y	Expansion requires new and updated equipment maintenance. More staff and operating hours	Y	No	—	—
Agency O	Y	Current facility is landlocked, not much room for expansion on site. Could develop facility on newly acquired land	—	Y	*As-needed, only if short on staff	—
Agency P	Y	Currently limited by the space/fleet/ experience. Explored this option in the past—did have existing request/application to purchase land behind the current facility, and IDOT already investigated the opportunity to build a (small) new facility nearby (with funding). regional maintenance center would require additional investment. Already help neighbor agencies and supply parts. Will be glad to learn more details.		N		In-house first, outsource if needed
Agency Q	—	—	—	—	—	—
Agency R	—	—	—	—	—	—

Agency	Willing to host a regional maintenance center?	If yes, expand old facility or having new ones?	If no, why?	Willing to outsource to a regional maintenance center?	Type of maintenance you might outsource?	If no, why?
Agency S	N	—	Possibly, would need a larger footprint for facilities. Is building a new $50 million facility, may be able to host regional maintenance center	Y	Higher end repairs (not in routine maintenance), major engine work	Space limitation
Agency T	Y	Regional maintenance center would have to be able to work on vehicles in fleet (specialized vehicles)	—	—	—	—
Agency U	N	—	—	N	Future successor of the official might be interested.	Federal state regulation, inability to hire good employee, personal background of community service: Giving back to the community
Agency V	Y	Both	—	No	—	Already able to do all the maintenance
Agency W	—	—	—	—	—	—

Additional Comments

The researchers' interviews were based on a predesigned questionnaire (see Appendix A), but they encouraged agencies/nonprofit organizations to share anything they find valuable and relevant. This section records the consensus of some agencies.

Zero-emission vehicles were often mentioned in the interviews, mainly referring to battery electric vehicles and hydrogen fuel cell vehicles. Currently, the CTA, Connect Transit, and the Greater Peoria Mass Transit District operate battery electric vehicles. The Champaign-Urbana Mass Transit District also operates two New Flyer Xcelsior XHE60 60-ft hydrogen fuel cell vehicles. Many agencies have expressed an interest in battery electric vehicles and hydrogen fuel cell vehicles. Some are already planning to acquire and operate battery electric vehicles or hydrogen fuel cell vehicles within the next five years (see the "Fleet Profiles" section).

Between battery electric vehicles and hydrogen fuel cell vehicles, more agencies show interest in the latter. Battery electric vehicles rely on batteries to store power, while long charging times and limited range make it challenging to operate such vehicles. This issue is even more obvious in rural areas, where daily vehicle mileage is usually higher, and there are few charging stations.

Hydrogen fuel cell vehicles can fill their hydrogen tanks in a short time and maintain operations for longer periods of time (e.g., ~250 miles). The fact that the Champaign-Urbana Mass Transit District's two hydrogen fuel cell vehicles can run from 6:30 a.m. to 5 a.m. the next morning is proof of this. It is not surprising that hydrogen fuel cell vehicles are more attractive to the transit agencies/nonprofit organizations interviewed. However, the researchers also recognize that hydrogen fuel cell vehicles and battery electric vehicles are new options to most Illinois agencies, and they also recorded much skepticism during the interviews. Below are some of the major issues.

Reliability is an issue that was mentioned repeatedly (often next to the limited range of battery electric vehicles). The technology of internal combustion engine buses is already very mature, but agencies must consider the potential failure rate that new technologies have. This is particularly important in rural areas. Smaller fleet sizes, a larger operating range, and harsher environments have put additional requirements on vehicle reliability.

Furthermore, technicians with experience in maintaining and repairing battery electric vehicles/hydrogen fuel cell vehicles are still very scarce. One agency said these advanced vehicles are completely unfamiliar to most operators in the United States, so the lack of technicians familiar with them is also a nationwide problem. The lack of technicians is not limited to those familiar with battery electric vehicles/hydrogen fuel cell vehicles—some agencies noted that it was also increasingly difficult to hire highly skilled general mechanics after the COVID-19 pandemic. This may lead to deterioration in repair quality. Although the COVID-19 pandemic has largely subsided, the transportation industry does not seem to have truly recovered from its impacts. In addition to potential support from manufacturers, building training programs via local higher education institutions is also considered a potential solution to the technician shortage.

An aging fleet with increased maintenance needs is another frequently mentioned topic. The CTA has received attention for its large fleet of vehicles 15 years and older, but the same problem occurs elsewhere in Illinois as one agency pointed out in the interview. This agency's fixed-route fleet consists of 16 vehicles, with an average vehicle age of 13 years. However, the agency's new vehicle procurement plans remain uncertain. They are also worried about sharply rising vehicle prices.

Ongoing supply-chain issues have severely affected vehicle maintenance. In early 2023, the Champaign-Urbana Mass Transit District's Managing Director, Karl Gnadt, noted the impact of disrupted supply chains on maintenance. Some vehicles (including two hydrogen fuel cell vehicles) had to be parked for longer periods of time given parts shortages and long waiting times, some even lasting several months. During the interview, some agencies also stated experiences with similar issues.

Many interesting options and questions were raised about how regional maintenance centers can help transit agencies/nonprofit organizations with their maintenance problems. For example, for battery electric vehicles/hydrogen fuel cell vehicle maintenance, would it be more efficient to centralize experienced technicians in regional maintenance centers to serve neighboring agencies' battery electric vehicle fleets than for each agency to hire their own technicians? Could regional maintenance centers serve as a depot with a larger pool of spare parts for agencies to use in case of shortages? Of course, regional maintenance centers can never completely resolve all challenges (e.g., new technologies, supply-chain issues). But many agencies are confident that a regional maintenance center could provide at least some solutions to their maintenance-related challenges.

STATE OF ILLINOIS AGENCIES/ORGANIZATIONS

While conducting the transit agency/nonprofit organization interviews, the researchers also reached out to six state of Illinois agencies/organizations and received three responses. The researchers sought to gain their perspectives on the current challenges with fleet maintenance, the performance of the two existing regional maintenance centers, and the financial and management prospects of establishing additional regional maintenance centers. In these interviews, interesting new ideas such as traveling technicians and service via telecommunications (e.g., video conferencing or virtual reality) were brought up and discussed.

This section summarizes the interview responses from IDOT's Bureau of Transit Operations (BTO) and Consolidated Vehicle Procurement Program (CVP) and from Western Illinois University's Rural Transit Assistance Center (RTAC). TRP members Jack Cruikshank and Zoe Keller attended these interviews as well.

Interviewees

- BTO: David Schafer
- CVP: Melissa Ohrwall and Jeffrey Waxman
- RTAC: Edward Heflin and David Patton

Q1: Would you please share your views on the ongoing challenges of transit fleet maintenance (technician and supply chains) in Illinois.

- BTO:
    - Aging fleet, maintenance cost (engine, transmission, etc.) increasing (30-50-100%) and eating up operating budget—depending on who is doing the maintenance.
    - Procurement challenge (engines and transmissions are costly ~5–6K), while there is a 10K threshold.
    - Supply chain issue (some of the agencies).
    - Will IDOT take vehicles back if they are not maintained well? Not at the moment. Also, even maintenance records on paper may not be done adequately in reality—so, we need the vehicles checked at regional maintenance center etc.
- CVP:
    - Getting technicians to look at the buses. Having purchase program to get parts efficiently. Recycle parts ("organ donors").
- RTAC:
    - Urban agencies have mass transit districts and good resources.
    - Rural areas: 39 mass transit districts with own staff—36 of them are in good shape, 42 counties are "pass-through," i.e., municipality (grantee) uses a grant to hire a nonprofit operator (who do not focus on transit and lacks motivation to do good preventative maintenance) ** Grantees get disengaged and do not keep a close view on fleet maintenance state.
    - Nine MTDs are self-operated.
    - 5310 (and 5311) funding service has the greatest needs for help—do not get the maintenance (from preventative to corrective) needed with knowledgeable persons. Some of the southern agencies use vehicles 500K miles or more.

Q2: What is the performance of the current two regional maintenance centers? Pros and cons as compared to more conventional maintenance practices.

- BTO:
    - Regional maintenance center being a governmental body, so agencies do not have to worry about procurement.

- Regional maintenance center provides specialized services that are not available in local shops.
- Springfield has more capabilities (and inventory of parts that are more accessible).
- Rockford has less business (~1,000 per year) since some rural counties try to keep expenditures local within their communities—however, the counterargument is that most of the transit fleet is based on federal money (so it is a responsibility to conduct regular maintenance and keep them in good shape).
- Regional maintenance centers do not have to keep a mark-up, and they can charge a lower cost.
- No contract or rules exist between the regional maintenance centers and IDOT.
- Might check if they are charging overhead.
- Many of the local agencies may share the same vehicle types that can benefit from regional maintenance center types of service.

- CVP:
  - Both regional maintenance centers might need more IDOT support. The one in Springfield is "booked-out"—maybe it needs better scheduling and coordination. They have a few regular "customers." Some agencies do not bring agencies for preventive maintenance inspections and tend to come in for more costly repairs that could have been avoided. Some existing regional maintenance centers could be struggling with keeping technicians—mostly serving their own fleet.

- RTAC:
  - Lacking regional maintenance center services in northern IL—mainly due to lack of qualified technicians, given competition with available private shops (less motivated to conduct preventive maintenance). Springfield regional maintenance center is covering the neighborhoods well.

Q3: Do you have any perspective on building additional regional maintenance centers, pros and cons? Financial viability and sustainability? Management challenges?

- BTO:
  - Funding sources needs to be confirmed (will apply for bus capacity funds next year).
  - Need to have upfront investment (inventory, and mechanic), building upon existing infrastructure facilities.

- Many of the southern counties are self-serving with good facilities, but without many providers.
- Some of the bigger agencies have not thought about the idea of hosting/promoting /supporting/using regional maintenance centers.
- Most of the rural agencies get maintenance money (65%) via the downstate assistance program)? RTA gets funding separately but may be interested in that too.
- Vehicles from a region (with funds support through downstate program) might best go through the regional maintenance center in the same region.
- Centralized information system that helps local agencies to keep track of vehicle state—challenge comes from execution given staff shortage; what type of database (maybe to modify existing ones), and how to make it work (possibly it can be procured for all agencies). Also, compliance.

- CVP:
  - Maybe first to understand the existing ones before exploring additional ones.
  - Capital bond funding can be used for supporting the local agencies to host regional maintenance centers (e.g., expanding facilities and hiring technicians). Regional maintenance center provides service revenues.
  - Might be helpful to sit down with the current regional maintenance centers (Spencer and Dan, from the TRP) and try to understand their experience.

- RTAC:
  - In the past, IDOT discussed with a few MTDs, but they declined—10 years ago, a third regional maintenance center was proposed.
  - Regional maintenance center needs to segregate the expenses (Springfield)—cover own fleet costs.
  - Regional maintenance center requires additional personnel (technician and manager) and facilities to handle the influx of demand—it is better to start with an existing facility/crew with good facility and personnel. Maybe IDOT should invest in specialty equipment/tools and distribute them properly. Maybe subsidize the cost for those regional maintenance center users.
  - The southern part of IL is well covered. Eastern vs. western IL needs local help.

Q4: Any new ideas for better maintaining IL's transit fleet (especially in rural areas), e.g., traveling mechanic station?

- BTO:
    - A great idea; however, execution challenges such as equipment (e.g., lifts) on the local garage, who is going to provide the overhead?
    - How about a regional trainer? CTA training program experience (50% about their own rolling stock, not too interested in using community college).
- CVP:
    - Might be a reasonable solution—flexibility of technician scheduling, and less queuing at centralized facilities; however, how portable are the tools and machinery, and what equipment must be on-site?
    - Some of the agencies may not have a local garage. Maybe plan by type of work, and technician? For more specialized technicians (battery-electric or fuel cell buses)—maybe need capabilities at regional maintenance centers? Training of technicians is a major concern among agencies for new types of vehicles. More specialized regional maintenance centers will help alleviate the challenges.
    - Having multiple regional maintenance centers will help reduce towing distance. Electric/hydrogen vehicles may have different needs, and maybe a combination of regional maintenance center/traveling/VR options can be suitable.
    - Some CTA have mechanics sitting in a van, and the van provides service on site—Mobile repairs. Vendors might be willing to go to the sites to provide service with the proper equipment.
    - Agencies need to be educated about the effectiveness of preventive maintenance (3k or 5k miles type work, e.g., transmission, body, engine work), which reduces needs for corrective repairs. St. Louis Metro keeps track of vehicle parts' status and provides reminders.
    - RTAC set up an email listserv or online forum ... where technicians can raise questions and get answers from peers, which has been successful for a lot of troubleshooting.
- RTAC:
    - Traveling maintenance technicians is good. However, the issue is that the local agencies may not know what they need.
    - Loaner vans and buses—buy a flatbed truck to tow them around. Maybe "trade-in" vehicles by driving in (old) and drive back (new).
    - AAA insurance model—each region hires tow companies to do the "shipping."

- Better to build regional maintenance centers as standalone vs. built upon existing agencies—maybe it is better to build many smaller regional maintenance centers rather than a few giant ones.

- IDOT needs to find good money to fund any of the above. Or spend the funds on educating agencies about preventive maintenance.

- IDOT is procuring alternative fuel vehicles (electric) ... while gas vehicles are not maintained well. Need for additional infrastructures.

- SIU (and many community colleges) has a program on vehicle maintenance and tech training—possibly do workshop and training on public transit—share with the sister project.

- CUMTD—hydrogen buses—good training opportunity

Q5: What is a suitable business model? Who sets the prices and keeps the revenue?

- BTO:

  - There is no existing guideline. Need to get through JCAR—joint committee on admin rules.

- CVP:

  - IDOT is collecting information and practice. Maybe IDOT will focus on the capital side, but maybe the operational side can be left for the local agencies/hosts.

  - Agencies such as Pace may not have thought about such regional maintenance center ideas.

PEER STATES

In addition to interviews with Illinois stakeholders, this study's researchers also received email responses from eight peer states, summarized below.

Respondents

- California: Brian Travis
- Michigan: Kevin Hohf
- Connecticut: Greg Towers
- Indiana: Todd Jennings and Brian Jones
- North Dakota: Becky Hanson
- South Dakota: Andrew Mentele and Monte Meier

- Nevada: Jake Miller

- Florida: Tony Brandin

Q1: Does your state directly support the maintenance of federally funded transit vehicles through regional maintenance centers, traveling technicians, or other coordinated efforts? If so, what are the parameters for transit agencies in your state to access this service?

- California: No.

- Michigan: No. We do not follow this model for agency vehicle maintenance. Each agency is responsible for either maintaining their own fleet with their staff or outsourcing their maintenance at a licensed repair facility.

- Connecticut: Partially. We have three state owned facilities that operate the CTtransit brand. We leverage the resources of our largest transit garage in Hartford to assist with some of the small providers maintenance/repair needs.

- Indiana: (i) INDOT's 5311 Program does not currently support maintenance of federally funded transit vehicles through any of these types of efforts. Most 5311 recipients obtain services through local vendors or for a few of our rural city systems, through use of their own city garage and maintenance departments. (ii) INDOT's state transit fund does support maintenance of urban (Section 5307) and rural (Section 5311) federally funded transit vehicles. Most urban recipients obtain maintenance services through their own maintenance departments. Most 5311 recipients obtain services through local vendors or for a few of our rural city systems, through use of their own city garage and maintenance departments.

- North Dakota: No.

- South Dakota: No. Currently we don't have anything developed, SDDOT is considering creating a committee to explore this option. All repairs are handled through local repair shops or staff employed through the individual agencies.

- Nevada: Our state does not directly support the maintenance of federally funded transit vehicles though regional maintenance centers, traveling technicians, or any other coordinated efforts. Our state may be unique in how limited our transit program is. The State has no transit operations itself. Our only role is to administer the grant programs for our rural transit agencies. All other transit agencies in small-urban and urban areas are designated direct FTA grant recipients. The small urban and urban transit agencies are managed by the MPOs in their area, and they handle all aspects of their programs including asset management and maintenance. For our rural transit agencies, the Nevada DOT does ensure that each agency has a maintenance plan in place. We receive monthly reports of maintenance from our rural agencies to verify that they are adhering to their maintenance plans. But each rural agency is in charge of their own maintenance plan.

- Florida: FDOT supports maintenance statewide through a contracted program with a local technical college. Training is provided on-site and at the technical college. FDOT fully funds this endeavor and reimburses the participants. Any agency technician or outsourced vendor providing services to the transit agency are eligible for the training.

Q2: What is the reimbursement/payment structure for service (i.e., do you reimburse the transit agency or pay the maintenance facility/technician directly)?

- California: No.

- Michigan: We reimburse rural agencies on actual expenses through their OARs at the designated federal and state rates for that year.

- Connecticut: Currently, this is handled through an existing AFE (authorization for expense) process. The provider would be billed by our garage and then submit the invoice to us for payment.

- Indiana: (i) Indiana's 5311 program recipients currently receive reimbursement for maintenance completed through the submittal of quarterly reimbursement reports to INDOT. The recipient received funds directly through a Pass-through Agreement with the county commissioners, planning commission, or other applicable entity. (ii) Indiana's state transit program recipients (Urban Section 5307) currently receive state reimbursement for maintenance completed through the submittal of quarterly reimbursement reports to INDOT. Urban recipients received state funds directly from INDOT. (iii) Indiana's 5311 program recipients currently receive state reimbursement for maintenance completed through the submittal of quarterly reimbursement reports to INDOT. The recipient receives state funds directly through a Pass-through Agreement with the county commissioners, planning commission, or other applicable entity.

- North Dakota: NDDOT reimburses the transit agency for work completed.

- South Dakota: We reimburse the Transit Agency after proof of payment has been provided.

- Nevada: The state reimburses our rural subrecipients for all of their expenses related to transit operations and maintenance.

- Florida: The FDOT contract is with a local technical college. Funds are provided to reimburse agency or technician expenses depending on the nature of travel involved. There is no cost for the specific training sessions. This training initiative is totally funded by FDOT.

Q3: What measures do you have in place, if any, incentivizing agencies to utilize specialized shops for maintenance instead of the Midas, Jiffy Lube, etc. down the street?

- California: None.

- Michigan: We do not incentivize or dictate the repair facilities that they use.
- Connecticut: The majority of our vehicles are buses that would not fall into this model.
- Indiana: No incentives at this time.
- North Dakota: None. North Dakota is mostly rural, and agencies use what they have available. We encourage them to spread service work around to support local businesses.
- South Dakota: Currently none. SD DOT has a committee made up of Transit directors whose goal was to determine if regionalized maintenance shops or a traveling technician was something to pursue. Committee is currently dormant and is in the process of being reviewed.
- Nevada: The state does not incentivize agencies to utilize any specialized shops for maintenance. Nevada's rural communities are very small and isolated compared to other states, and this means that the options the transit agencies have when it comes to maintenance, or any other expense, will be very limited. There are not typically any specialized shops near the operation area.
- Florida: "Specific measures in place" would be limited. FDOT does not approach these efforts negatively with penalties. FDOT policies require a higher than minimum requirement and much effort is made to make the agencies aware of the importance of effective maintenance practices. FDOT does, in some cases, provide financial assistance to agencies with equipment purchases, shop upgrades, and improved electronic data collection.

Q4: Additional comments or suggestions?

- California: Caltrans does not get directly involved with maintenance. Local transit agencies do, however, receive grants from CA to build their own local/regional maintenance facilities. Also, depending on their size and sophistication, some smaller transit systems subcontract their operations out to venders that maintain the vehicle fleets directly. The one area that I foresee direct state involvement in vehicle maintenance would be for intercity bus, but that's not current reality. I do believe vehicle maintenance—how it's going to be done, is something that was looked at in our California Intercity Bus Study. That study is still in draft and has not been released just yet.
- Michigan: We determine a reimbursement rate for our rural transit agencies (subrecipients) based on the total federal operating funds we are allocated each year from FTA and using their submitted annual budget totals. For state operating funds, the governor approves the amount of appropriated funds for this as part of our annual budget. Those funds are then distributed from a prescribed formula as laid out from requirements within Michigan Act 51. Vehicle maintenance expenses are reported on the transit agencies' annual budgets and then reimbursed via the formulas set above. The agencies report the total they plan to spend on vehicle maintenance within their budgets. They do not get granular with the amount per oil change, or the number of oil changes performed in a year, that would be logged within their

own internal books. Maintenance technician hours would fall under payroll or labor, which are other lines reported to us in full on their budgets. Hours and rates again would be stored with the agencies, we do not require that they submit that information.

- Connecticut: State is paying for the maintenance 100%; there is no federal funds.

DISCUSSION

Overall, Illinois transit agencies positively view the regional maintenance center model. Even those agencies/nonprofit organizations that were not planning to host regional maintenance centers or use regional maintenance center services also shared their positive views with expectations and suggestions.

Since almost no two agencies have the same fleet sizes, composition, or maintenance strategies, regional maintenance centers must therefore adapt to local conditions and exactly address local needs (e.g., in terms of the type of services and capacity). They should be open to offering different service options, such as information collection and management, spare parts storage, in-shop preventive maintenance and repair services, traveling technicians/stations, and even virtual services through telecommunication and/or virtual reality. They must provide these services at reasonable prices and repair times and possibly provide options for local logistics (e.g., towing buses), thereby ensuring their competitiveness. If possible, regional maintenance centers should at least be able to mitigate some of the problems that the aforementioned agencies had. These challenges undoubtedly place high demands on planners and regional maintenance center operators.

The remainder of this section discusses some characteristics and conditions of a transit agency that would make them ideal candidates for a successful regional maintenance center.

- **Spatial Proximity and Accessibility**. Any future regional maintenance centers should be strategically located in the state such that most intended customers (rural transit agencies) would pass by or be nearby. However, their overlap in coverage should be minimized. This issue was highlighted in the literature review (Beruvides et al., 2009) and in many of the agency/nonprofit organization interviews. A set of rural populations with strong transit services and vehicle maintenance needs should ideally surround any new regional maintenance centers, while being far away from other/existing regional maintenance centers or maintenance facilities.

- **Facilities and Equipment Maintenance**. Many interviewed agencies/nonprofit organizations currently own facilities that are already serving their own fleet, and some of them are in the process of building new facilities. IDOT should consider information such as construction year, square footage, building details (such as bay doors, washing bays, parking availability, etc.), inventories of equipment maintenance/tools, and neighboring land availability and land prices when determining candidates for regional maintenance centers. The regional maintenance centers should have good structural, plumbing, and electrical conditions as well as capability to provide a vehicle loaner program, road call service, and wrecker service.

- **Human Resources**. An ideal candidate for a regional maintenance center should have exceptional human resources capabilities (mechanic technicians, administrative personnel, and non-technical personnel) to provide technical service to rural transit agencies. Among these, mechanic technicians are the most critical and must have higher technical expertise than local shops/mechanics (especially regarding transit vehicles and alternative fuel engines). A high ratio of mechanical technicians to the number of vehicles serviced could reveal the efficiency of the facilities' current maintenance operations. An ideal candidate should also actively seek continuous training, education, and certification opportunities for its employees.

- **Maintenance and Service Provision Practice**. An ideal candidate should have a strong history of efficient preventive maintenance programs and safety inspection procedures. Such a history is indicative of the agency's general administrative practices and will reveal potential issues if its facility were to become a regional maintenance center—if the facility can handle the expected technical and administrative workload increases. Also, a facility is likely to be a strong candidate for a regional maintenance center if it is already serving neighboring agencies.

- **Financial Sustainability**. As discussed in Beruvides et al. (2009), all invested regional maintenance centers are expected to be self-sustainable after the initial investment. Hence, strong regional maintenance center candidates should require low capital investment, low startup costs, low operating expenses, high revenue potential, and low local competitions.

- **Prospects for Expansion**. An ideal regional maintenance center candidate should have the capability to expand over time with the growth of rural transit maintenance demand.

CHAPTER 4: PRELIMINARY REGIONAL MAINTENANCE CENTER NETWORK DESIGN

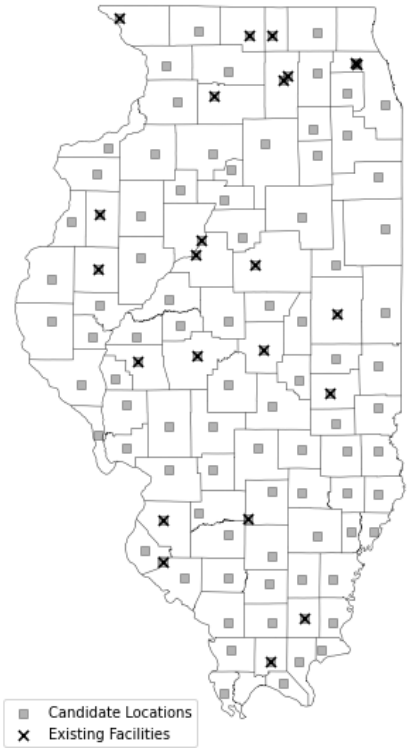
MODEL FORMULATION

As discussed in Chapter 3, the deployment of additional regional maintenance center infrastructure in Illinois is a complex multidimensional problem that requires careful investigation. This section, however, presents a preliminary network design model to illustrate how such decisions can be systematic, data-driven, and fact-based. Given this project's short period, the researchers made many simplifying assumptions in this model, and, hence, the results are not intended to be implementable recommendations.

The researchers consider the existing facilities of interviewed transit agencies/nonprofit organizations (including the two existing regional maintenance centers at Rockford and Springfield) as well as the reported distribution of fleet maintenance demand in this model. They seek to provide sufficient coverage in Illinois while minimizing systemwide maintenance costs.

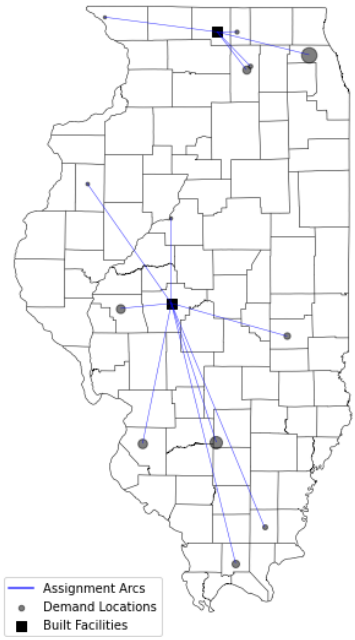
To construct this model, the researchers first identified all possible candidate locations for new regional maintenance centers. The 23 current transit agencies are obvious candidates, given that they already have existing facilities and technicians. The size of the facilities at these agencies are normalized to that of the Sangamon regional maintenance center size by square footage into a fractional number between zero and one. The Sangamon regional maintenance center is 58,851 sq ft.

To better cover Illinois, the researchers further identified the centers of all Illinois counties that did not already have a transit agency as approximate representatives of additional regional maintenance center candidate locations. As such, there are 105 candidate locations. The researchers assumed that IDOT would consider investing *P* new regional maintenance centers and ignored land price differences at different locations. They plotted these candidate locations in Figure 7(a).



(a) Distribution of candidate locations for regional maintenance centers

(b) Distribution of unmet demand of 23 agencies



(c) Nearest assignment of unmet demand to Rockford and Sangamon regional maintenance centers

Figure 7. Map. Distribution of (a) candidate locations for regional maintenance centers, (b) unmet demand of 23 agencies, (c) nearest assignment of unmet demand to Rockford and Sangamon regional maintenance centers.

The researchers then identified the transit fleet vehicle maintenance needs based on the survey responses from Chapter 3. For simplicity, they did not differentiate the maintenance needs of different types of buses but used the fleet size as a direct proxy for maintenance demand.

To correlate the fleet size to maintenance facility size, the researchers used the Lee-Ogle Transportation System (LOTS) as a baseline. The survey showed that their facilities supported their fleet without providing much service to other agencies. LOTS serves 26 buses in an 8,165 square foot facility. It is 0.139th of the size of the Sangamon Mass Transit District's regional maintenance center. The researchers normalized the agency's fleet maintenance demand into the equivalent of the Sangamon regional maintenance center's capacity as follows:

$$\text{Normalized demand} = \frac{\text{agency fleet}}{\text{LOTS fleet}} \times \frac{\text{LOTS facility size}}{\text{Sangamon RMC size}}$$

Figure 8. Equation. Equation to normalize an agency's fleet maintenance demand to an equivalent Sangamon regional maintenance center capacity.

Furthermore, the researchers assumed that each agency's existing facilities should first serve their demand and only outsource unmet demand to regional maintenance centers. They thus computed the unmet demand as the difference between the agency's normalized demand minus its normalized facility capacity, as follows:

$$\text{Unmet demand} = \max\{0, \text{Normalized demand} - \text{Normalized facility capacity}\}$$

Figure 9. Equation. Equation to calculate the unmet demand of each agency.

All these conversions are summarized in Table 9.

Table 9. Local Agency Facility Sizes, Fleet, and Approximate Unmet Demand

Agency	# facilities	Total Sq. ft	Technicians employed	% Sangamon size	Total fleet size	Fixed route	On-demand/ Paratransit	Unmet demand
Agency M	1	61,066	5	1.038	61	42	19	0.000
Agency B	0	0	0	0.000	10	0	10	0.053
Agency P	1	83,587	25	1.420	132	118	14	0.000
Agency F	1	14,816	2	0.252	32	25	7	0.000
Agency L	0	0	3	0.000	40	24	16	0.213
Agency H	1	56,464	4	0.959	41	18	23	0.000
Agency K	1	0	—	0.000	147	0	0	0.784
Agency D	0	0	0	0.000	26	0	26	0.139
Agency C	1	8,266	3	0.140	9	5	4	0.000
Agency J	1	36,437	14	0.619	101	53	48	0.000
Agency Q	1	4,829	2	0.082	21	0	21	0.030
Agency A	1	8,165	2	0.139	26	0	26	0.000
Agency T	10	1,144,524	300	19.448	2240	700	1540	0.000
Agency G	6	61,684	17	1.048	211	8	203	0.078
Agency O	3	9,429	44	0.160	64	0	64	0.181
Agency W	3	14,060	6	0.239	140	0	140	0.508
Agency E	1	58,851	18	1.000	87	62	25	0.000
Agency R	1	0	—	0.000	54	42	12	0.288
Agency N	1	6,087	2	0.103	26	0	26	0.035
Agency S	1	10,112	2	0.172	44	0	44	0.063
Agency I	1	2,310	1	0.039	15	0	15	0.041
Agency V	0	0	0	0.000	48	48	0	0.256

The researchers plotted the unmet (nonzero) demand of the 23 agencies in Figure 7(b) as well, where the sizes of the dots indicate the relative magnitude of unmet maintenance demand. If IDOT does not build any new regional maintenance centers, the system is actually infeasible, because the capacity of the current Rockford and Sangamon regional maintenance centers cannot serve all unmet demand. However, if the researchers ignore the capacity of these current regional maintenance centers and assign all demand to the nearer of the two regional maintenance centers, the pattern is shown in Figure 7(c).

The researchers were then able to build the mathematical model. They denoted the set of transit agencies by notation I, and considered them as the demand points. Each agency $i \in I$ has an unmet demand of v_i, which is given by the last column of the table. They defined J as the set of candidate locations where base stations could be installed. At most, one regional maintenance center can be

installed at each location $j \in J$, with a service capacity of 1 (of the Sangamon regional maintenance center). The existing facility capacity at a candidate *j* is f_j, which corresponds to the column "% of Sangamon's size" in the table. Variables $X \coloneqq \{x_j\}$ determine regional maintenance center locations, where $x_j = 1$ if a regional maintenance center is installed at location j or 0 otherwise. Since Sangamon and Rockford already are the two regional maintenance centers, the researchers fixed the values of the variables for those locations at 1.

For complete coverage, each demand point $i \in I$ is required to be covered by a regional maintenance center or its own existing facility. Variables $Y \coloneqq \{y_{ij}\}$ determine the demand coverage assignment, where $y_{ij} \in [0,1]$ is the fraction of unmet demand i that is covered by a facility located at j. We use $d_{ij} \geq 0$ to denote the distance between demand point i and facility at j (measured via the highway network from Google Maps), as shown in Table 10.

Table 10. Distance Matrix between Candidate Locations and Transit Agencies (Truncated)

	Adams County, Illinois	Alexander County, Illinois	Bond County, Illinois	Boone County, Illinois	Brown County, Illinois	Bureau County, Illinois	Calhoun County, Illinois	Carroll County, Illinois	Cass County, Illinois	Champaign County, Illinois	Christian County, Illinois
St. Clair County Transit District	169.9	115.9	59.8	312.9	131.7	228.8	79.9	285.8	116.0	190.2	97.5
Rides MTD	284.0	77.1	121.7	393.8	241.6	331.9	189.8	379.0	225.9	204.2	159.2
Champaign-Urbana MTD	191.9	244.9	141.0	201.7	164.6	139.8	185.4	201.8	127.9	12.0	87.9
South Central Transit	225.5	116.3	44.4	295.9	183.2	234.0	131.3	284.9	150.8	141.6	81.8
Greater Peoria MTD	109.6	301.4	143.1	146.8	92.1	54.7	166.0	112.1	73.9	91.5	94.2
Springfield MTD	88.6	230.0	71.6	211.7	73.4	127.6	94.3	184.7	36.4	90.3	25.6
Shawnee MTD	295.5	41.3	133.2	405.3	253.1	343.4	201.3	390.5	237.4	215.7	170.7
Bloomington-Normal Public Transit System	133.7	285.7	136.5	146.9	114.3	84.9	159.4	146.9	97.7	54.6	87.6
West Central MTD	58.9	226.5	102.1	247.5	31.6	143.6	62.0	192.6	17.4	127.9	61.5
City of DeKalb	236.5	402.3	253.1	31.3	219.7	79.1	276.0	72.0	214.3	171.2	204.2
Voluntary Action Center	242.0	407.8	258.6	30.7	225.3	84.6	281.5	72.0	219.8	176.7	209.8
City of Macomb	53.6	294.4	160.5	212.9	43.1	133.5	110.8	142.4	50.6	142.3	110.0
Lee-Ogle Transport. System	198.1	393.6	229.8	69.3	181.4	32.3	249.0	38.5	164.6	162.5	181.0
City of Decatur	139.0	214.4	81.7	193.2	111.7	131.2	132.5	193.2	75.0	53.9	30.2
Tazewell County	103.0	298.1	139.8	154.3	85.5	68.6	142.1	119.1	67.4	94.7	90.9
Coles County	190.8	192.6	88.7	245.1	163.5	183.2	176.3	245.2	126.8	55.5	60.7
Jo Daviess County	220.1	464.3	305.9	104.8	211.4	116.2	279.1	45.9	206.4	261.0	257.1
Warren County	83.3	349.1	210.8	181.3	74.7	102.0	142.4	110.9	82.2	159.2	162.0
Boone County Council on Aging	254.4	419.9	270.7	7.5	237.6	96.7	293.6	70.2	231.9	188.9	221.9
Clearbrook	271.1	390.9	273.9	53.7	251.7	120.6	296.8	115.6	235.1	153.9	225.0
ComWell	184.6	92.7	80.9	334.0	152.8	249.9	101.0	306.9	137.1	211.3	118.6
Pace Suburban Bus Division	272.0	389.9	274.8	54.4	252.6	121.5	297.7	116.3	236.0	153.0	225.9

The mathematical formulation of our network design model, following the framework of P-median design is summarized as follows.

$$\min \sum_{j \in \boldsymbol{J}} d_{ij} v_i y_{ij} \tag{1}$$

$$\text{s.t.} \sum_{j \in \boldsymbol{J}} y_{ij} \geq 1, \ \forall i \in I, \tag{2}$$

$$\sum_{j \in \boldsymbol{J}} x_j \left(1 - f_j\right) \leq P, \tag{3}$$

$$\sum_{i \in \boldsymbol{I}} v_i y_{ij} \leq x_j, \ \forall j \in J, \tag{4}$$

$$x_j \in \{0,1\}, \ \forall j \in J \backslash \{\text{Sangamon, Rockford}\}, \tag{5a}$$

$$x_j = 1, \text{ if } j \in \{\text{Sangamon, Rockford}\}, \tag{5b}$$

$$y_{ij} \in [0,1], \ \forall i \in I, \ j \in J. \tag{6}$$

Figure 10. Model. Mathematical formulation of regional maintenance center network.

The objective function (1) consists of the total demand-weighted distances between demand and facilities, wherein the optimal solution gives the network design with the least total travel distances for maintenance buses. Constraint (2) ensures that each agency's unmet demand is covered by at least one built regional maintenance center. Constraint (3) guarantees that IDOT will invest no more than P new regional maintenance centers, and that the investment level is reduced accordingly if a regional maintenance center is built on top of an agency's existing facility (of capacity fj). Constraint (4) ensures that the total demand allocated to every built regional maintenance center does not exceed its capacity, and if no regional maintenance center is built at a location, then assigns no demand there. Constraints (5a) and (5b) ensure that investments on the regional maintenance center is binary, and that two regional maintenance centers already exist in Sangamon and Rockford. Constraint (6) ensures that the assignments of maintenance demand are nonnegative.

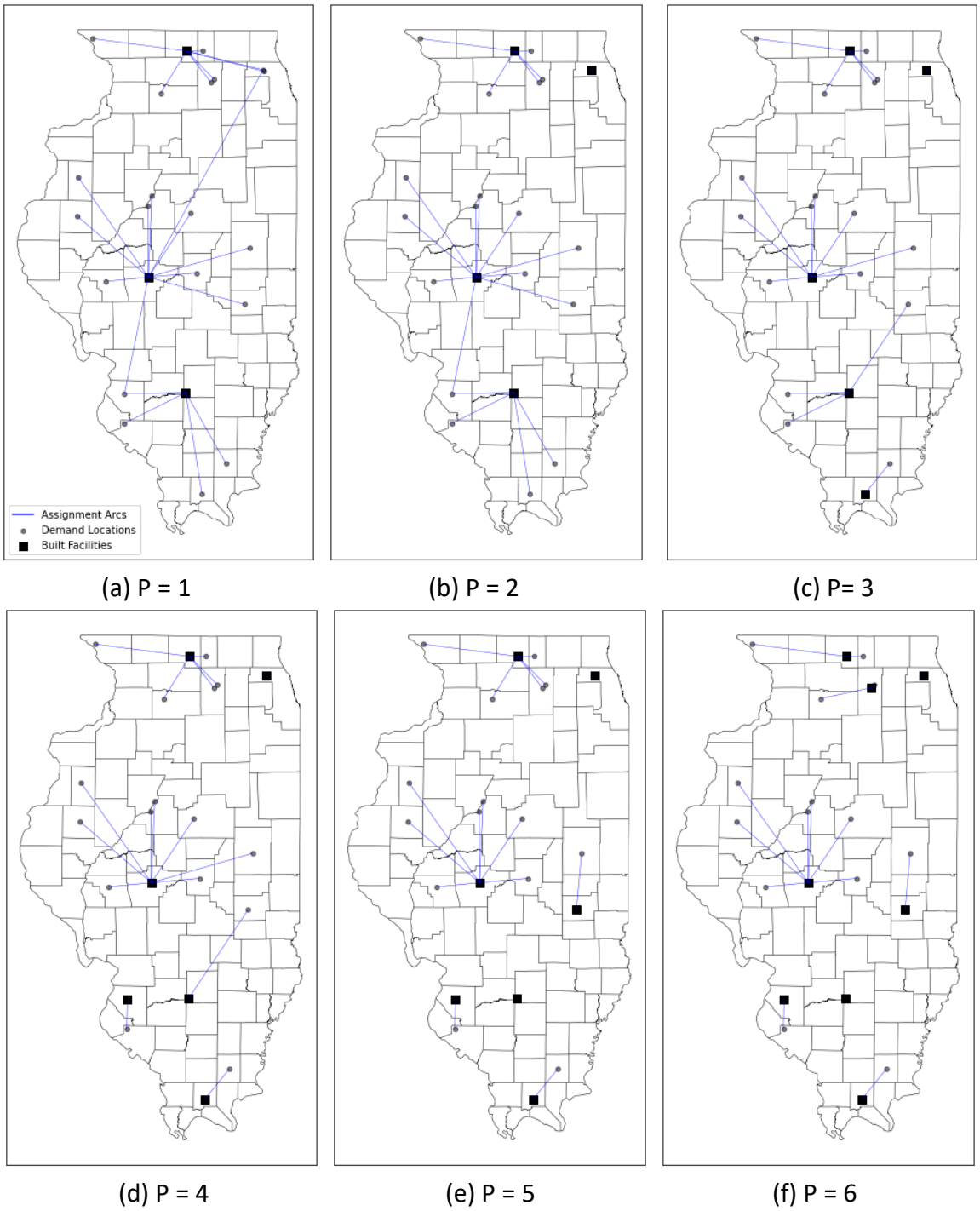
The mathematical formulation is a mixed-integer linear program, which is NP-hard and may take a significant time to solve. However, given the relatively small size of the Illinois case (23 demand points and 105 candidate locations), commercial solvers such as CPLEX and Gurobi can solve the formulation within seconds of computation time. Table 11 details the list of parameters and variables that were used in the model.

Table 11. Variables and Parameters Used in the Model

Variable Symbol	Variable Description
I	set of transit fleet location at agencies
J	set of candidate locations for regional maintenance center installation
v_i	unmet demand at agency i
$X \coloneqq \{x_j\}$	1 if a regional maintenance center is installed at location *j*; or 0 otherwise
$Y \coloneqq \{y_{ij}\}$	fraction of unmet demand from location i that is assigned to a facility at location j
P	The number of new regional maintenance centers that IDOT can build within its budget
f_j	Existing facility capacity at j

PRELIMINARY RESULTS

The researchers applied the mathematical model from the "Model Formulation" section to Illinois for a range of P values from 1 to 6 new regional maintenance centers. The optimal locations of new regional maintenance centers, together with the two existing ones, are plotted in Figure 11. The assignments for those facilities with zero demand value are also included.



(a) P = 1 (b) P = 2 (c) P= 3

(d) P = 4 (e) P = 5 (f) P = 6

Figure 11. Maps. Design of regional maintenance centers under P = 1, 2, 3, 4, 5, 6.

Table 12 shows the optimal locations of the newly built regional maintenance centers.

Table 12. Optimal New Regional Maintenance Center Locations Under P = 1, 2, 3, 4, 5, 6

P	**New regional maintenance center locations (besides Rockford and Sangamon regional maintenance centers)**
1	• South Central Illinois Mass Transit District
2	• South Central Illinois Mass Transit District • Clearbrook
3	• South Central Illinois Mass Transit District • Clearbrook • Shawnee Mass Transit District
4	• South Central Illinois Mass Transit District • Clearbrook • Shawnee Mass Transit District • St. Clair County Transit District
5	• South Central Illinois Mass Transit District • Clearbrook • Shawnee Mass Transit District • St. Clair County Transit District • Coles County
6	• South Central Illinois Mass Transit District • Clearbrook • Shawnee Mass Transit District • St. Clair County Transit District • Coles County • City of DeKalb

Despite the high demand in Cook County, South Central Illinois Mass Transit District is probably a good location to build the first new regional maintenance center mainly because of the coverage it provides to the southern demand locations as well as the agency's relatively large existing capacity. Clearbrook is also a favored choice to provide coverage in the large demand locations in northern Illinois. If more resources are available, both southern and western options such as St. Clair County Transit District, Shawnee Mass Transit District, and Coles County can be good options because of their proximity to some of the demand points.

The associated objectives (i.e., normalized demand weighted by travel miles) decrease monotonically with the addition of regional maintenance centers, as shown in Figure 12. The case of $P = 0$ is used as the benchmark, indicating the transportation cost needed if only the current two regional maintenance centers are being used (even though their capacities are violated). As indicated by the plot, the objective reduction is over 60% with merely two new regional maintenance centers.

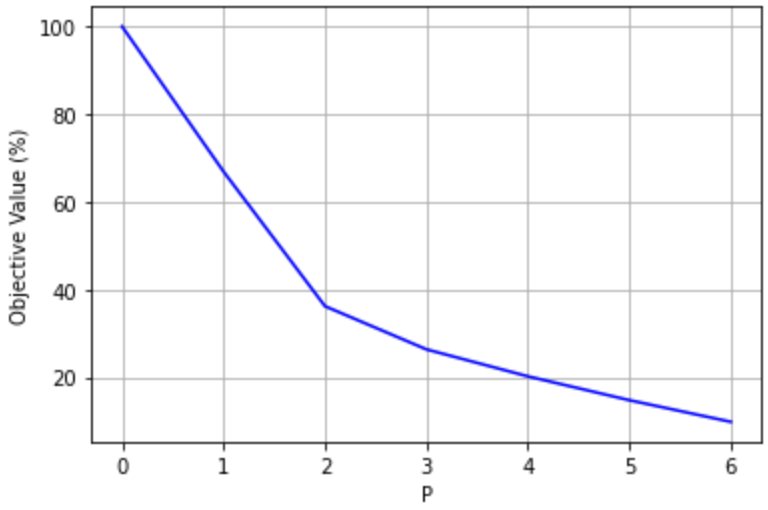


Figure 12. Graph. Relative objective savings as regional maintenance center investment increases.

CHAPTER 5: CONCLUSION

The researchers investigated transit vehicle maintenance processes, maintenance needs, and potential opportunities associated with building additional bus maintenance capacities (e.g., regional maintenance centers) in Illinois. The researchers conducted a literature review, stakeholder interviews, and preliminary model analysis to help the Illinois Department of Transportation (IDOT) collect information on how capital and operating funding could be better used to support public transit agencies in both urban and rural areas. They made the following key findings in this study:

- Many rural agencies/nonprofit organizations recognize that their aging fleets are a severe problem and anticipate acquiring electric or hydrogen fuel cell buses in the next five years. They worry about inadequate infrastructure and technician expertise to support these new vehicles as well as the limited range of electric buses and these vehicles' reliability issues.
- Roughly 97% of buses owned by the agencies interviewed are internal combustion vehicles. Gasoline is the mainstream fuel for cutaway buses.
- A similar proportion of urban and rural agencies/nonprofit organizations follow the original equipment manufacturer's maintenance guidelines. They use a wide variety of fleet management software.
- Severe supply-chain issues exist for vehicle parts.
- Most agencies/nonprofit organizations performed all maintenance in-house or outsourced only major repairs (e.g., on engine/transmission) to local mechanics shops. They are generally open to outsourcing major repairs to regional maintenance centers.
- A little over half of the agencies/nonprofit organizations felt that their current technician staffing numbers were sufficient, but they need training.
- About half of the agencies/nonprofit organizations were open to the idea of hosting regional maintenance centers. They believe that regional maintenance centers have the potential to concentrate highly skilled technicians and alleviate statewide challenges with transitioning to alternative fuel vehicles.
- Most southern transit agencies are more self-sufficient than northern, eastern, or western agencies given less competition for skilled technicians with local mechanics shops.
- Generally, peer state DOTs do not directly support maintenance programs through regional maintenance centers or similar facilities. Rather, they support local agencies' maintenance efforts through grants.

This study's findings lay the foundation for more effective planning of a better network of regional maintenance centers. With additional efficiency processes surrounding maintenance overall, these findings will provide long-term benefits to IDOT and partner agencies by reducing vehicle down time, decreasing maintenance and towing costs, and allowing for greater tracking of maintenance techniques in coordination with similar agencies across the state.

REFERENCES

Antich, M. (2022). Inflationary price pressures increase maintenance costs. *Automotive Fleet*, March 7. https://www.automotive-fleet.com/10162928/inflationary-price-pressures-increase-maintenance-costs

Beruvides, M. G., Simonton, J. L., Waters, N. M., Ng, E., Chaivichitmalakul, S., Chiu-Wei, C. C., ... & Moon, P. (2009). The concept of a regional maintenance center. *Journal of Public Transportation*, *12*(3), 105–118. http://doi.org/10.5038/2375-0901.12.3.6

Beruvides, Mario G., et al. (2010). Site assessment instrument for regional maintenance center. *Journal of Public Transportation*, *13*(1), 39–54. https://doi.org/10.5038/2375-0901.13.1.3

Bladikas, A. K., & Papadimitriou, C. (1986). Analysis of bus transit's maintenance efficiency using section 15 data. *Transportation Research Record*, *1066, 22-29.*

Callaghan, L., Lynch, S., & Northeast Advanced Vehicle Consortium. (2005). *Analysis of electric drive technologies for transit applications: battery-electric, hybrid-electric, and fuel cells* (No. FTA-MA-26-7100-05.1). United States. Federal Transit Administration. Office of Research, Demonstration, and Innovation.

Centeno, G., Chaudhary, R., & Lopez, P. (2005). Developing standard times for repair activities for transit vehicles: A systematic approach. *Transportation Research Record*, *1927*(1), 112–122. https://doi.org/10.1177/0361198105192700113

Christer, A. H., & Waller, W. M. (1984). An operational research approach to planned maintenance: modelling preventive maintenance for a vehicle fleet. *Journal of the Operational Research Society*, *35*, 967-984. https://doi.org/10.1057/jors.1984.193

Deliali, A., Chhan, D., Oliver, J., Sayess, R., Godri Pollitt, K. J., & Christofa, E. (2021) Transitioning to zero-emission bus fleets: State of practice of implementations in the United States. *Transport Reviews*, *41*(2), 164–191, https://doi.org/10.1080/01441647.2020.1800132

Dickens, M., & Neff, J. (2011). *2011 Public Transportation Fact Book Appendix A: Historical Tables*. American Public Transportation Association.

National Academies of Sciences, Engineering, and Medicine. (2005). *A guidebook for developing and sharing transit bus maintenance practices*. The National Academies Press. https://doi.org/10.17226/13562

Ng, E. H., Beruvides, M. G., Simonton, J. L., Chiu-Wei, C. C., Peimbert-Garcia, R. E., Winder, C. F., & Guadalupe, L. J. (2012). Public transportation vehicle maintenance and regional maintenance center: An analysis of existing literature. *Engineering Management Journal*, *24*(3), 43–51. https://doi.org/10.1080/10429247.2012.11431946

Purdy, J. E., & Wiegmann, J. D. (1987). Vehicle maintenance: Cost relationship and estimating methodology. *Transportation Research Record*, 1140.

Roberts, G. L., & Hoel, L. A. (1981). *Survey of transit bus maintenance programs in Virginia* (Report No. VHTRC 82-R2). Virginia Transportation Research Council.

Schiavone, J. J. (2010). *Preventive maintenance intervals for transit buses*. Transportation Research Board. https://doi.org/10.17226/22965

Schiavone, J. J. (1997). *Monitoring bus maintenance performance* (No. Project J-7).

Texas Department of Transportation. (2003). *Maintenance Management and Safety Guide: Public Transportation Division*. Texas Department of Transportation.

Venezia, F. W. (2004). *Maintenance Productivity Practices (No. 54)*. Transportation Research Board, The National Academies Press. https://doi.org/10.17226/23049

Zukowski, D. (2023). To close budget gaps, transit agencies face hard decisions in 2023. *Smart Cities Dive*, January 31. https://www.smartcitiesdive.com/news/public-transit-agencies-2023-budget-gaps-ridership-zero-fare/641116/

APPENDIX A: QUESTIONNAIRE TO TRANSIT AGENCIES/ NONPROFIT ORGANIZATIONS

Illinois Center for Transportation Project R27-SP58
Investigating Statewide Transit Maintenance Needs

Questionnaire

Through this project, researchers are studying the current network of regional maintenance centers in Illinois and how that system can provide long-term benefits to IDOT and partner agencies by reducing vehicle down time, decreasing maintenance and towing costs, and allowing for tracking of maintenance techniques in coordination with similar agencies across the state. Additionally, this project will investigate maintenance labor rates and training needs (in coordination with a separate ICT Special Study on maintenance technician training needs).

This study will assess IDOT's current transit fleet maintenance practices, processes, needs, and resource availability. This document of interview questions will be used to structure interviews, to help identify current maintenance issues, as well as to capture stakeholders' perspectives on pricing (e.g., willingness to pay, or willingness to accept, a price for a maintenance service).

A. Fleet Profile

1. In this section, please answer questions about your agency's bus fleet makeup by fixed-route and demand-response/paratransit. For each sub fleet, please provide averages for fleet age, daily miles, and maintenance cost, and breakdown by fuel types within those fleets. Please also fill out the average condition rating of each type of bus in the column "Average condition." The condition rating is rated from 1 to 5, where 1 indicates no defects, 2 indicates minor/limited defects, 3 indicates periodic defects, 4 indicates moderate deterioration and exceeds expected life, and 5 indicates excessive defects and need complete replacement.

Fixed-route fleet

Fleet size(s)	Average fleet age	Daily miles	Average condition	Overall maintenance cost	Fuel types breakdown

On-demand/paratransit fleet

Fleet size(s)	Average fleet age	Daily miles	Average condition	Overall maintenance cost	Fuel types breakdown

2. If your agency has plans to procure new revenue vehicles in the next 5 years, please list them in the following table.

Manufacturer/ Model	Fuel Type	Seat Capacity	Quantity	Source of Funding

B. Maintenance Practices

In this section, we define maintenance to include inspections, repairs, replacements, and overhauls/refurbishments. Inspections include service line inspections, operator inspections that are conducted daily, and preventive maintenance inspections that are conducted at regular intervals (e.g., at 60k miles). Repairs only include reactive maintenance and repairs made to defects identified during inspections.

1. Do you feel that the maintenance manuals provided by the manufacturer meet your agency's needs? If not, please comment on the additional maintenance procedures practiced by your agency.

If NO, please explain.

2. What metric is used by your agency for scheduling preventive maintenance? HOURS, MILES, or OTHER?

3. Do you use software to track maintenance and repairs? If yes, which program do you use?
   _____

B. 1 Preventive Maintenance Inspections

Please answer the questions in this section for each unique bus model for which your preventative maintenance schedule is different. If your maintenance schedule varies significantly for buses of the same model from different years, please complete the following questions separately for each year.

MODEL(s):_____ YEAR(s):_____

4. If your preventative maintenance intervals somewhat deviate from the manufacturer's suggested intervals, please indicate the differences in the table below under the "Intervals" column. If not, you may leave that column blank.

5. Please indicate the "Location" where you conduct preventive maintenance for each system, either in-house (including maintenance performed by a contracted public transit operator), or you contract out the work. If inspections are conducted in-house, but repairs are contracted out, please indicate this in the "Comment" column. If contracted out, please provide the name of the contracted company/shop(s).

System	Intervals	In-House (Y/N)?	Contracted? If yes, which Company?	Comment
Engine and powertrain (Exhaust, Hydraulics, Driveline)				
Drive axle (Wheels, Brakes, Suspension, Steering)				
Body and chassis (Wheelchair ramp/lift)				
Others (Electrical, AC, Air system)				

C. Agency Resources and Capabilities

6. Please list the maintenance facilities owned by your agency.

7. Do you coordinate your maintenance efforts with those of any non-transit vehicles, such as a county's snowplow or sheriff's fleet? YES NO

8. What is the average age of your maintenance facilities? _____

9. How many maintenance technicians are employed by your agency?
   Full-time _____ Part-time _____

10. Do you feel as though this number is sufficient to support your fleet operations? YES NO

11. Does your agency employ any ADA-certified technicians? YES NO If yes, how many? _____

12. How are technicians at your facility trained to inspect, maintain, and repair ADA equipment?

13. Please check which types of maintenance services are provided at your facilities.

	Preventive maintenance inspections
	Minor repairs (e.g., alternator swap)
	Major repairs (e.g., engine swap)
	Body and chassis structural repairs

Regional maintenance centers are facilities that allow transit agencies to purchase maintenance services directly from the regional maintenance center instead of outsourcing it. These facilities may offer a less expensive alternative to outsourcing maintenance work, as they have transit-specific expertise and parts. If properly executed, regional maintenance centers can reduce maintenance and operation costs for all parties involved.

14. With this in mind, would your agency be interested in hosting a regional maintenance center? YES NO

    a) If yes, would the regional maintenance center require expansion of a current facility or potentially a new facility? Please provide a short explanation.

15. Would your agency be interested in outsourcing maintenance work to a regional maintenance center, assuming the service is cost-effective and convenient? YES NO

16. If you answered yes to the previous question, please describe the type of maintenance you might outsource to a regional maintenance center.

17. If you answered no to question 12, please indicate any obstacles.

D. Maintenance Expenses

18. What percentage of your agency's total revenue vehicles maintenance costs is preventive?
    _____

19. If your agency tracks preventive maintenance costs, please complete the following table. We divide preventive maintenance into three levels: A, B, and C which correspond to frequent (e.g., 6,000 miles), semi-frequent (e.g., 24,000 miles), and infrequent inspections. Please provide the average cost per inspection of each type. If your agency is able to further detail maintenance costs to differentiate bus types (e.g., diesel, diesel-electric, battery-electric), please complete the table below for each type.

20. Please also give a rough estimate on an upper limit, if any, of the cost of each preventive maintenance level that your agency would be willing to pay (maybe include the fees, and the cost of transportation). You may simply indicate a percentage of the current cost (e.g., 120%, or 100%).

Preventive Maintenance Level	Current cost per inspection	Upper limit of cost (% of current)
Level A		
Level B		
Level C		

APPENDIX B: VIDEO CONFERENCE INTERVIEW SCHEDULE

	Agency	Interview Date/Time	Lead Officials
1	Lee-Ogle Transportation System	6/20/2023 8:30 a.m.	Greg Gates, John Stinson, Steve Davis, and Marcus Cox
2	Boone County	6/20/2023 4:00 p.m.	Erin Marshall
3	ComWell	6/21/2023 8:30 a.m.	Mark Bollmann
4	Coles County	6/21/2023 4:00 p.m.	Cheryl Shutt
5	Springfield	6/23/2023 8:30 a.m.	Steve Schoeffel
6	Decatur	6/23/2023 4:00 p.m.	Lacie Elzy
7	Harrisburg	6/26/2023 8:30 a.m.	Adam Lach
8	Macomb	6/27/2023 8:30 a.m.	Miranda Lambert
9	Warren County	6/27/2023 4:00 p.m.	Morgan Lewis
10	Peoria MTD	6/28/2023 8:30 a.m.	Steven Green
11	Clearbrook	6/28/2023 4:00 p.m.	Don Frick
12	City of DeKalb	6/30/2023 8:30 a.m.	Mike Neuenkirchen and Brian Van Hine
13	Connect Transit	7/6/2023 3:00 p.m.	Charlie Busse
14	Tazewell County	7/11/2023 4:00 p.m.	Dawn Cook
15	Shawnee MTD	7/17/2023 8:30 a.m.	Mike Pietrowski
16	Champaign—Urbana MTD	7/19/2023 8:30 a.m.	Josh Berbaum
17	Jo Daviess County	7/19/2023 4:00 p.m.	Nicole Hermsen
18	St. Clair County Transit	6/20/2023 via email	Ken Sharkey
19	Voluntary Action Center	7/26/2023 4:00 p.m.	Tracy Smith
20	Pace	7/28/2023 3:00 p.m.	Lindsey Umek
21	McLean County (SHOW BUS)	7/28/2023 4:00 p.m.	Laura Dick
22	West Central Mass Transit District	7/21/2023 8:30 a.m.	R. Jean Jumper

	Agency	Interview Date/Time	Lead Officials
23	South Central Transit	8/9/2023 8:30 a.m.	Sara Nollman-Hodge
24	IDOT Bureau of Transit Operations	08/08/2023 9:00 a.m.	David Schafer
25	IDOT Consolidated Vehicle Procurement Program	08/04/2023 3:00 p.m.	Melissa Ohrwall and Jeffrey Waxman
26	IDOT Rural Transit Assistance Center	7/25/2023 9:30 a.m.	Edward Heflin and David Patton
27	IDOT Central Management Services	7/25/2023 2:30 p.m.	Peter Gribble
28	American Public Transportation Association	9/20/2023 9:00 a.m.	Carita Ducre, Lisa Jerram, Marie Benton, Coach Cherise, Michael Kunkle, and Cherise Myers
29	Caltrans + California Air Resources Board + Humboldt Transit Authority	8/3/2023 2:00 p.m.	Yachun Chow and Greg Pratt

APPENDIX C: EMAIL QUERY TO PEER STATES

To: Members of the Council on Public Transportation and Transit Management Program

From: Rebecca Anger, AASHTO, on behalf of Illinois DOT

Subject: Transit Management Alert – Tell Us About Your Vehicle Maintenance Process

Deadline: August 9, 2023

The Request:

The Illinois Department of Transportation (IDOT) Office of Intermodal Project Implementation, in partnership with the University of Illinois Urbana-Champaign, is studying transit maintenance processes across Illinois. IDOT is seeking information from other state DOTs on your role in transit vehicle maintenance, especially if there is a coordinated statewide effort. IDOT would greatly appreciate if anyone would be willing to speak to their own fleet maintenance oversight, processes, and any lessons that may be applicable to IDOT's situation for Illinois transit vehicles.

IDOT's questions can be found below. If you have information not captured by the questions, please do not hesitate to share that with IDOT as well.

Background:

Through IDOT's study with the University of Illinois Urbana-Champaign, IDOT is investigating current and best practices to provide maintenance for the more than 3,000 public transit and non-profit human service agency transit vehicles across Illinois. Illinois transit providers have a varied transit fleet that includes cut-aways, minivans, and buses which may be gasoline, diesel, electric, or hydrogen powered. IDOT currently has two Regional Maintenance Centers run by urban transit agencies and is considering expanding this network to support the highest quality of maintenance for IDOT's federally funded fleet.

Please Respond:

1. Does your state directly support the maintenance of federally funded transit vehicles through Regional Maintenance Centers, traveling technicians, or other coordinated efforts? If so, what are the parameters for transit agencies in your state to access this service?

2. What is the reimbursement/payment structure for service (i.e., do you reimburse the transit agency or pay the maintenance facility/technician directly)?

3. What measures do you have in place, if any, incentivizing agencies to utilize specialized shops for maintenance instead of the "Midas, Jiffy Lube, etc. down the street?"

4. Can we contact you directly for follow-up questions?

Please take a moment to complete this Transit Management Alert and assist us with your insight about your state's transit vehicle maintenance process. Please email responses to Jack Cruikshank, Transportation System Planner, at John.Cruikshank@Illinois.gov, and Rebecca Anger, ranger@aashto.org.


Illinois Department
of Transportation


ILLINOIS