MADISON BUS SIZE STUDY

Final Report

February 2014

Madison Area T•P•B Transportation Planning Board
A Metropolitan Planning Organization (MPO)

Metro

Wisconsin Department of Transportation

NELSON NYGAARD

IN ASSOCIATION WITH:

EDWARDS ENGINEERING CONSULTANTS, LLC
BAY RIDGE CONSULTING

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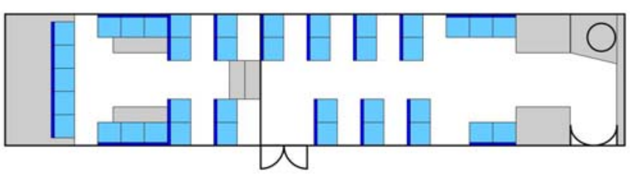
1 REPORT SUMMARY

PURPOSE OF STUDY

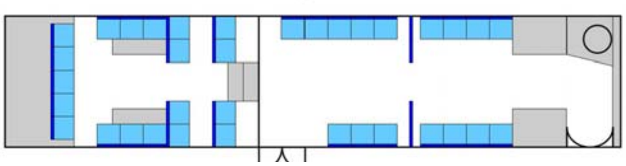
This study undertakes a detailed analysis of Metro Transit bus routes to determine whether some routes might be better-suited to smaller or larger vehicles based on rider demand. It also includes supplemental analysis on the introduction of larger or smaller buses into the fleet, including financial implications, an analysis of whether or not the existing maintenance facility and bus stops can accommodate large buses, and effects of these buses on vehicle scheduling.

Metro currently operates a fleet of standard 40-foot transit buses with 35 to 40 seats.

40-foot bus—38 seated + 15 standees = 53



40-foot bus, perimeter seating—35 seated + 21 standees = 56



Historically, Metro has used only one bus size to meet the transit needs of the Madison area. Metro currently operates a fleet of about 210 standard 40-foot transit buses with about 35 to 40 seats. The agency has made extensive use of non-scheduled extra buses, and it has recently moved to perimeter, or center-facing seats, on all new bus acquisitions to increase standing space to assist with overcrowding on busy routes. One of the key issues explored in this study was if the introduction of larger buses could offset the need for extra buses thus freeing this equipment and service hours for new service. The study makes recommendations on how Madison should proceed in future vehicle acquisitions to implement the study findings.

BUS FLEET MAKE-UP CONSIDERATIONS AND OPTIONS

Within the transit industry, conventional wisdom once held that maintaining a uniform fleet, all identical buses, promotes efficiency. The evolving industry trend, though, suggests it may be more efficient to operate with a more varied fleet tailored to meet the specific transit needs of the area being served. On high demand routes, larger capacity vehicles can move more passengers with marginal increases in acquisition and operating cost, or, in some cases, provide the same capacity with greater efficiency, using one bus in place of two buses. At the other end of the spectrum, on low demand routes, increasing fuel and maintenance costs have made cost savings, although marginal, more attractive when operating buses with smaller passenger capacity on routes suited to the smaller capacity. Small buses use about 10% less fuel than a standard transit bus. The overarching consideration in any bus purchase and deployment decision must effectively and efficiently meet the transit riding needs of the community, compliment the characteristics of the transit network, and be financially sound.

The essential tenet of transit fleet acquisition and sizing is that the fleet be designed to the needs of the transit system when the most buses are deployed for service, such as the morning and afternoon peak commute periods. It makes no financial sense to have buses solely for off-peak use that cannot be used during peak periods. In addition, the Federal Transit Administration (FTA) – the major funding agency for bus capital – does not support this practice. . The FTA funds bus acquisition at up to 80% of the total cost, but they also require that agencies follow the FTA fleet management requirements. The FTA will not fund buses that are not utilized in peak periods except for a reasonable number of buses for maintenance spares, set at a maximum of 20% of peak deployment

In the US there are three large bus choices: articulated (jointed 60-foot) buses with typical seated capacities of 50-60 people, over-the-road motor coaches (typically used for intercity service) with capacities of 50-55 people, and double-decker buses with seated capacities of 70-80 people. A typical "standard" transit bus seats up to about 40 people. Due to the service and transit facility characteristics of Madison, only articulated buses have been considered as feasible additions to the Metro bus fleet.

There are many choices and types of smaller buses, each with advantages for different conditions. Some smaller buses are built on light truck chassis with seating capacities of 10 to 20 people, such as vehicles currently in use for Monona Transit and Metro+Plus paratransit. These vehicles excel in applications where they are only used a few times a day or have limited stops because they wear out quickly when subjected to the rigors of typical urban transit service. Medium duty truck chassis have also been crafted into buses with seating capacity in the 20 to 30 passenger range. These vehicles are better suited for more rigorous use than those built on light duty chassis, but are more expensive and are also not well suited to urban transit operations because of their high floors and uncomfortable rides on suspension systems designed for loaded trucks. For this reason, it is common in the transit industry to have separate fleets of light-duty paratransit vehicles and heavy-duty fixed-route vehicles.

The third type of small bus is essentially a shortened 30- to 35-foot version of the standard 40-foot transit bus built on a heavy duty bus chassis. The seating capacity is normally 20 to 30 people. These buses are designed specifically to meet the daily rigors of urban transit service. For that reason, only 30-foot heavy duty transit buses were considered for this study. Metro Transit does not currently provide any services that would be appropriate for either light- or medium-duty transit vehicles. In the future, regional express or rural service, if offered, may make such buses worth considering. The small heavy duty bus focused on in this study costs more than the other two small bus options in purchase price and slightly less than a standard 40-foot transit bus. The concept of using the same vehicle for low-ridership, peripheral fixed-route service and paratransit service with a hybrid medium-duty vehicle surfaced during the study and may be worthwhile to investigate in the future, but is not within the scope of this investigation.

As vehicles in Metro's fleet age and are replaced, they generally transition from all-day work to peak only work and end their useful lives as trippers (performing only a few daily trips on school days) for Supplemental School Day Service. One challenge to face with small buses is finding a role for older small buses that will likely not have a role in the Supplemental School Day Service network. These small buses may need to continue to provide main-line service throughout their useful lives, effectively exposing riders and operators to older equipment.

Figure 1: Bus Types

Light-Duty Small Bus *Typical Uses:* Demand Response service and low demand fixed-route services *Length:* 16 to 28 ft *Seats:* 10 to 22	
Medium-Duty Small Bus *Typical Uses:* Demand Response and low demand regional express fixed-route services *Length:* 25 to 35 ft *Seats:* 20 to 30	
Heavy-Duty Small Bus *Typical Uses:* Low demand fixed-route services *Length:* 30 ft *Seats:* 22 to 30	
Standard Bus *Typical Uses: Fixed-route urban transit service* *Length:* 40 ft *Seats:* 35 to 38	

<table>
<tr><td>Articulated Bus
Typical Uses: High-use fixed-route transit service, bus rapid transit
Length: 60 ft
Seats: 50 to 54</td><td></td></tr>
<tr><td>Over-the-Road Coach
Typical Uses: Inter-city bus service, chartered trips
Length: 40 to 45 ft
Seats: 50 to 55</td><td>
</td></tr>
<tr><td>Double-Decker Bus
Typical Uses: Long distance commuter service and inter-city bus service
Length: 42 ft
Seats: 77</td><td></td></tr>
</table>

UNIQUE CHARACTERISTICS OF MADISON

Madison has unique geography that increases the complexity of transit service design. This, in turn, affects decisions on how best to meet consumer needs and operate efficiently. The isthmus at the center of the major employment area, joined immediately to the west by a major university, means that buses carrying workers and students have to traverse many of the same pathways to reach customer destinations.

Metro Transit uses a pulsing "Transfer Point" system where peripheral routes connect to core service for continuing service to central Madison with a timed connection. From a customer perspective, boarding a bus and remaining on-board to their ultimate destination is far more convenient than transferring at some point in the trip. However, many riders do not travel to or from downtown Madison and facilitating transfers in the periphery reduces travel times by an order of magnitude for these cross-town journeys. These factors contribute to the complexity of the Metro system and the current approach of a uniform bus fleet. It also contributes to the public perception that Metro operates "big empty buses." Buses often begin their trips nearly empty but accumulate passengers gradually as they traverse along their route.

For example, a state worker who resides in Middleton is very likely to be joined by University of Wisconsin – Madison (UW) students and staff. At the outer ends of the route the bus is well below capacity, but as it approaches the western end of the UW, it will have many people. At the outer ends of such a route, people observe buses that are well below capacity, even on Metro's busiest routes. For those individuals who do not have an opportunity to observe the same bus downtown with a standing load, it is easy to understand their perception that the bus is under-utilized.

Several times in the study, questions were raised concerning changes to the basic design of transit services in Madison and how that might influence the need, or desirability, of a bus fleet of mixed size. Generally, service and network design should be tailored to meet the transit needs of the area and the vehicle size must be based on that design rather than forcing a service design to accommodate a particular vehicle size. In the final analysis, the study team identified a few locations where routes could be split in different places to accommodate small and large buses but did not explore hypothetical large-scale system restructures.

HOW THE STUDY WAS CONDUCTED

Early in the study, several locations near downtown Madison, near the UW and at transfer points were identified as likely points where buses are most crowded. Buses were observed at each of these locations during peak periods on two different sets of dates. The end result was that about 20 to 60 individual trips were observed for each route and the number of passengers on-board was recorded at each location. Using this method, the study team was able to ascertain the maximum number of people on the bus on each trip. The data was then used make an initial bus size determination by applying size criteria to the observed loading patterns (see Figure). The size criteria used was not having more than 20% of trips above a "comfortable full load" for a standard bus or more than 10% of trips above a comfortable full load for a small bus (see Figure 3). The more stringent criterion of exceeding the comfortable load on a small bus is based on small buses typically not having a second door for passengers to exit, which could lead to significant circulation problems with full loads.

Comfortable loads were defined as a bus having a few more people than seats – 30 passengers for a 30-foot bus and 40 passengers for a 40-foot bus. In most cases, these loads would have a few empty seats and five to ten standees. The bus is "full" but passengers can generally circulate. More people could physically fit on the bus, but when loads approach 50 or more for a 40-foot bus, conditions are cramped and uncomfortable for standees. Bus load examples are displayed in Figure 4.

The sizing criteria also take into account the fact that loads vary on a daily basis. One day a particular trip approaching downtown may be well above the maximum capacity, but the day after the bus may only have a full seated load. Using this methodology means that a significant number of trips would need to be regularly overloaded before a bus size is increased; it is not designed to accommodate the "peak of the peak" loads, which would result in an excessive vehicle size for all but a handful of trips.

Figure 2: Maximum Load Selection

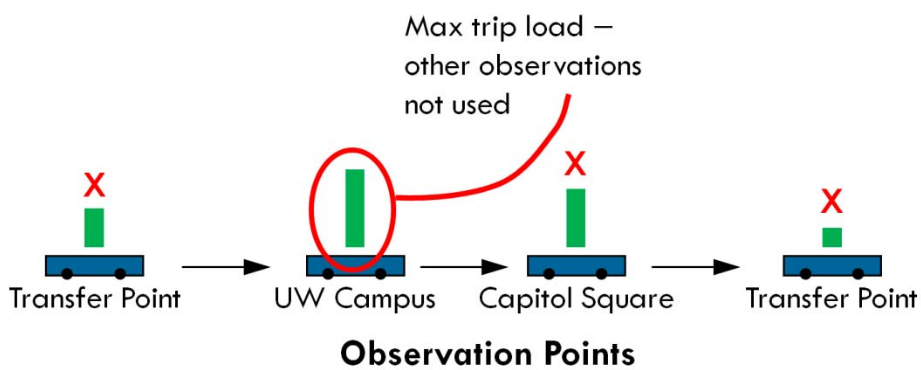


Figure 3: Bus Size Decision Chart

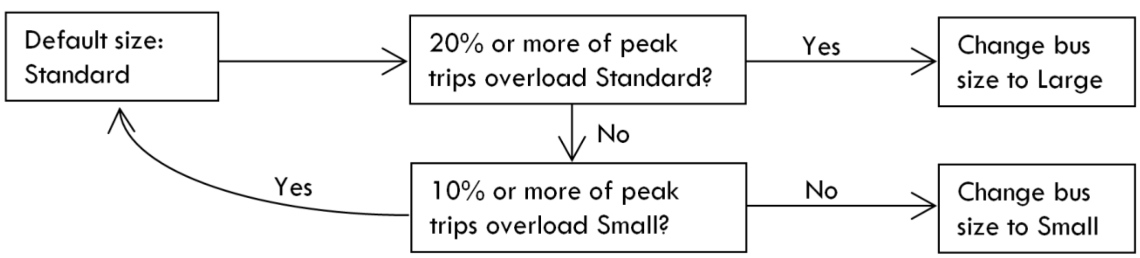


Figure 4: Bus Load Examples

Seated Load

Standing Load

Crush Load

WHAT WE FOUND

Based on data collected a number of routes appear to be strong candidates to switch from standard buses to large buses and a small number of routes are good candidates to switch from standard buses to small buses. These routes are illustrated in

Figure 5 on page 1-11.

Large Buses – The use of large buses shows significant promise to reduce overcrowding on some routes. The analysis shows potential for up to 48 standard buses to be upgraded to larger 60-foot articulated buses, 40 buses in service and 8 spares. Routes 80 and 84 present the most immediate opportunity. In addition, routes 2, 15, 28/56/57, 37/38, 44/48, 71/74, and 72 all demonstrate a need for increased capacity that could be provided by use of larger buses. Note that routes shown as pairs, e.g. 28/56, are operationally connected to each other. This is often called interlining where a bus will move from route to route rather than being assigned to a single route. This is done primarily to improve operational efficiency and reduce the number of buses required to operate service.

The study identified three substantive issues that must be resolved before moving ahead with a large bus acquisition. First, large buses take up more parking space than standard buses and there is no available space to accommodate them.

A second problem involves finance: the introduction of large buses would cause an increase in Metro's operating and capital costs. Besides the cost impact of expanded bus storage and maintenance capacity, large buses are more expensive to purchase and cost more to operate than standard buses. A new financial plan must be assembled to ensure the new bus capacity is financially affordable.

A third issue associated with Metro adding large buses involves whether or not the buses could be accommodated by existing system infrastructure. There are many locations, in particular the transfer points, where the additional length of articulated buses may create significant challenges. The solutions to these challenges may lead to additional costs. These needs must be accounted for by some combination of modifying infrastructure and changing operating practices, e.g. reducing the amount of pulse scheduling or lengthening bus stops.

Metro has a current and proven need to invest in bus capacity. There will be an increase in operating and capital costs for such an investment that could range from $650,000 up to $1.8 million per year depending on the number of larger buses acquired and how they are deployed.

However, those costs do not include costs to resolve bus storage and maintenance capacity issues that must be addressed before large buses can be assimilated into the daily operations of Metro.

Small Buses - With today's transit system, routes 13, 17, 34, 39, and 52 could operate with small buses without causing crowding problems. These routes use five buses to provide service during peak periods. With the inclusion of a spare, they would justify the purchase of six total small buses. In addition, Route 31 is a new route that could likely be operated with one small bus, but it began operations after the data collection occurred so additional analysis is needed to verify this.

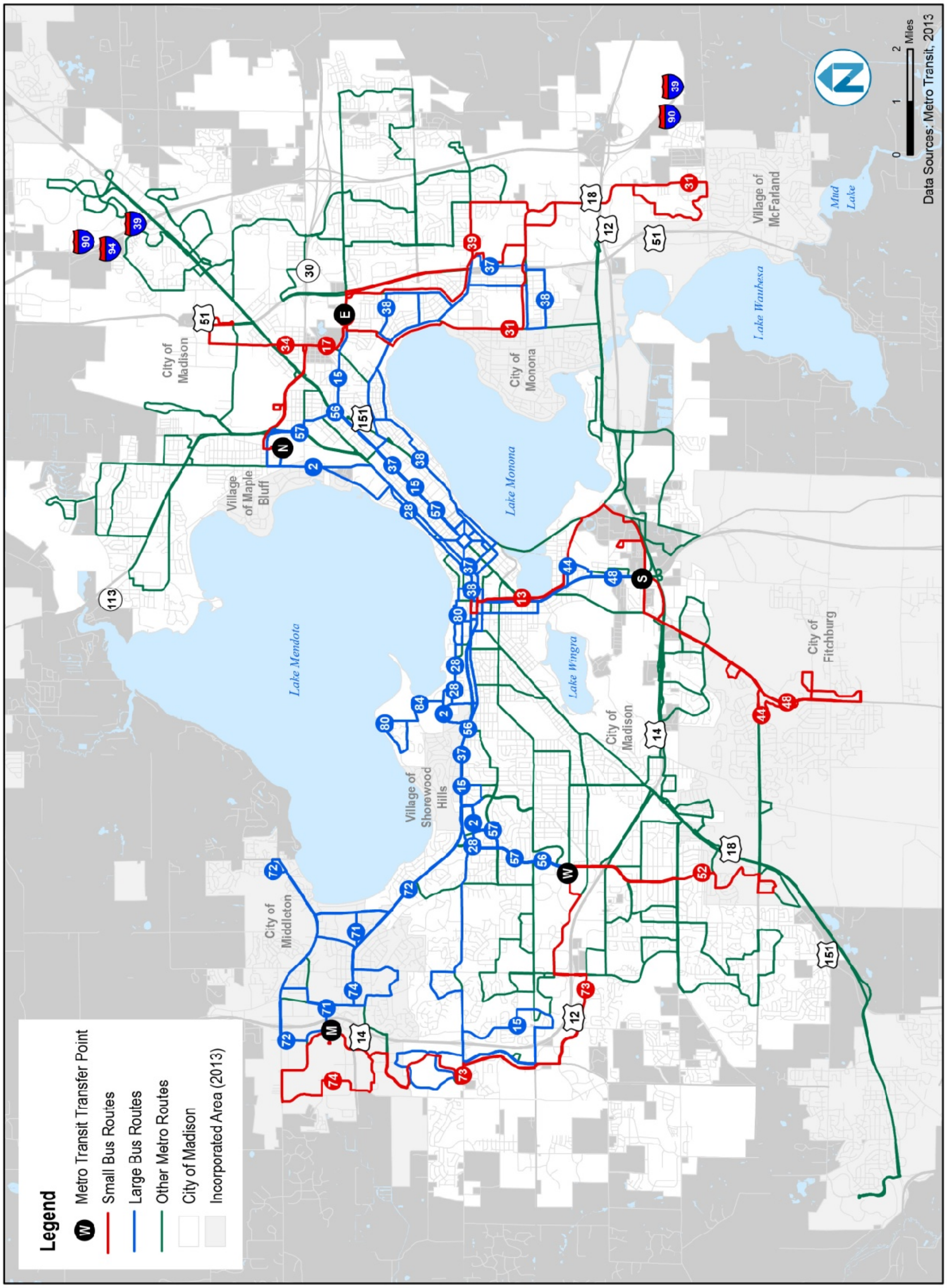
There are other routes that could utilize small buses, but only if the routes were restructured. In some cases this would involve separating the central Madison part of the route from the peripheral tail. It is uncertain if such a restructure is desirable from a rider perspective and efficient from an operating perspective. These routes include Routes 44/48, 73, and 74 west of the Middleton Transfer Point. If all of these possibilities aligned, Metro could deploy a fleet of up to thirteen small buses.

The assimilation of small buses into the Metro fleet is possible under today's conditions. But there are a limited number of routes where they are an appropriate fit in terms of capacity versus demand.

The main benefit of small buses is to dispel the "big empty bus" perception and a modest decrease in fuel use and greenhouse gas emissions. It appears the introduction of ten small buses would not affect system costs significantly.

Bus Storage and Maintenance Facility – Metro's current bus storage capacity is insufficient to accommodate any additional buses, large or small, or to accommodate large buses replacing standard buses. The options to resolve this limitation include: increasing the size of the current bus garage, acquiring additional bus storage and maintenance in another location, and/or reducing the total fleet size. This latter option is undesirable because the system would not be able to operate as it does today with fewer vehicles.

Figure 5: Small and Large Bus Routes



CONCLUSIONS AND RECOMMENDATIONS

Large Buses - There are significant opportunities to introduce large buses, but they come at a cost. Route 80, Route 84 and University Avenue corridor routes such as Route 2 are the highest priority because they serve the most crowded areas and have consistent all-day service with significant loads occurring throughout the day. Metro must determine if, and to what extent, standard-sized buses can be replaced with articulated buses given the increased costs associated with large buses. Metro must also address the adequacy of the bus storage and maintenance facility before replacing any standard buses with large buses. The current garage has no capacity to store or maintain any articulated buses.

Large buses will end up costing Metro more to acquire and operate as part of the fleet. The exact increase depends on a number of factors. In the maximum deployment where articulated buses are substituted for standard buses on a one for one basis on all routes where peak overcrowding was observed and the extra capacity would be utilized, a total of 40 articulated buses would be required, plus 8 additional as spares for a total of 48. Total operating and annualized capital costs to the system of this deployment are estimated to be an increase of $1-2 million per year. In some cases, it may be possible to reduce the number of peak trips based on the higher capacity of large bus. In these cases, the cost of providing service during peak periods could be reduced, but the higher operating cost of the large buses throughout the day would more than offset that cost savings. In this scenario the other significant consideration is that the frequency of service on some of Madison's busiest routes would be reduced. That is a trade-off that must be considered.

Small Buses - Small buses may be appropriate for a few routes in the Metro system. If a decision is reached to include small buses in the fleet, it is recommended that at least ten buses are acquired to efficiently manage and maintain. A smaller number could be acquired and deployed, but the inefficiency of such a small number in a fleet of over 200 would very likely reduce or eliminate any real or perceived benefits. These inefficiencies include increased labor costs associated with planning for, maintaining, and operating two different types of vehicles, as well as the necessity of maintaining a parts inventory for a small fleet of buses.

The deployment of ten small buses is unlikely to create a financial benefit to Metro. In fact, the inclusion of small buses could slightly increase system costs due to the logistics of moving buses on the periphery of the area into and out of service. Based on industry research and life cycle cost evaluation, any cost savings from the introduction of small buses will be marginal. This is primarily because the majority of bus operating costs cover the bus operator's wages, benefits, as well as those of supervision and maintenance.

Alternatively, the introduction of a small but reasonable number of small buses may improve public perception by addressing the perceived problem of "big empty buses" operating outside the urban core. In addition, smaller buses use less fuel, and, therefore, emit fewer greenhouse gases. While the integration and deployment discussed in this study is focused on peak periods, deployment of a fleet that emits fewer greenhouse gases in off-peak time periods could contribute to measureable reductions in transit-generated greenhouse gases while maintaining community mobility.

If the current route system were extensively restructured, a larger fleet of small buses could be deployed while maintaining customer-friendly capacity on lower demand routes. The downside of such an approach is that some riders would need to transfer, thereby losing their one-seat ride of today. An in-depth examination of this strategy was not part of the scope of this study but may be appropriate for a future transit development plan.

Summary – Overall, the study team believes Metro should proceed with caution if there is support for moving to a diversified fleet with large or small buses. There are significant issues that must be addressed before moving to diversify the bus fleet.

The first issue is a decision on funding and construction of an additional, or replacement, bus storage and maintenance facility that can be designed to serve articulated buses.

The second issue is a decision on the future of a bus rapid transit (BRT) system and a better understanding of how that relates to the need for articulated buses. Many of the potential routes for articulated buses are the same corridors under consideration for BRT. A BRT system would likely be initially funded with the federal government paying up to 50% of project capital costs. Metro may wish to wait for this assistance before embarking on a full deployment of large buses on these routes.

Finally, if Metro's future growth plans include new regional express service and service to new areas, potentially made possible by a regional transit authority (RTA), there would be an increased need for small buses that are appropriate for this service.

Another set of considerations lies ahead as Madison launches the effort to construct a "transportation master plan." This plan will consider the application of all modes and their related infrastructure requirements. Given the magnitude of the capital funding decisions confronting Madison Metro, it would be appropriate for this study to feed into this broader planning effort. The master plan should address funding priorities and articulate modal priorities, but the availability of funding is also to be considered. State funds are not available for transit capital projects, and federal funds have decreased since new federal legislation was enacted.

WHAT DOES THIS MEAN FOR RIDERS AND THE PUBLIC?

On balance the majority of riders would notice little or no difference in their transit trips if the fleet is diversified besides the noticeably different layout of the vehicles. Some riders may need to transfer in place of today's one-seat-ride because of scheduling changes needed to accommodate a diversified fleet. Some riders will have a seat where today they stand, while some will find a place to stand instead of being passed up.

Aside from these technical and financial considerations there are the considerations related to public opinion. Regardless of the outcome of this study, public perception will persist that Metro is operating "big empty buses" and is not making the best use of public funds. This is a very common public perception of transit agencies. To gain public confidence that Metro should invest in maintenance facilities, BRT, or large buses, it may be necessary for Metro to clarify for others how the system operates and what constraints exist. Even if the financial results are close to neutral for small buses, there may be value in small reductions in fuel use and greenhouse gas emissions as well as a better match between demand and capacity on a few routes.

In the long term, is fleet diversification positive or negative for riders? No one can fully forecast the future, but transit agencies throughout the U.S. operate diversified fleets. There is no overall assessment to label their experience as positive or negative. The one universal finding is that fleet diversity has allowed systems to be more flexible in meeting of the transit needs of the communities they serve.

2 PROJECT OVERVIEW

Metro's Final Report of the City of Madison Long-Range Metro Transit Planning Ad Hoc Committee (June 2008) recommended that "Metro should develop a scope of work for an outside group to review the pertinent issues related to determining whether smaller, larger, or a mix of buses should be used to serve the Metro area." Metro has consistently responded to suggestions about using different sized buses that it is not practical to use smaller buses because of passenger capacity constraints, particularly during peak periods. To give this issue a fresh look, the Bus Size Study was led by the Madison Area Transportation Planning Board (MPO), with Nelson\Nygaard as a consultant, with assistance from Metro Transit in order to relieve any perceived or actual bias influencing results.

This project provides a detailed analysis of the Metro Transit main-line fixed-route bus system in order to determine whether any routes might be better-suited to either smaller or larger vehicles. The study then was to determine what types of financial and other impacts could result from developing a transit fleet with different vehicles sizes. While conventional wisdom once held that a uniform vehicle size promoted efficiency, the evolving trend is recognizing that it may be more efficient to operate with a fleet with a variety of vehicle sizes. On high demand routes, larger capacity vehicles can move more passengers with the same resources, or the same number of passengers with greater efficiency. As fuel and maintenance costs have increased, use of small buses may produce gains in efficiency and may be more environmentally beneficial. However, for any size vehicle, purchase and deployment must be balanced with capacity and service quality objectives.

In addition to main-line fixed route service, Metro also provides Supplemental Schoolday Service – fixed route bus service designed to facilitate trips to middle schools and high schools. This service prevents overloading the main-line routes with students while eliminating transfers for students. Supplemental Schoolday Service was not examined as part of this study. These routes typically use the older vehicles in Metro's fleet and can carry high volumes.

This project adopts a data-driven process for assessing vehicle capacity needs. The project decision tree is shown in Figure 7. Initial recommendations for small or large vehicle route candidates were based on data collection and analysis of peak load volumes. Following the initial recommendations, a full analysis was conducted of potential impacts including changes to current interlining and blocking, peak vehicle needs, costs, facilities impacts, fleet lifecycles, and MPO and Metro staff input. This report summarizes each step of the analysis and provides guidance that will inform Metro Transit's decision-making regarding whether to propose to introduce varying bus capacities into the fleet and how to ensure that any changes to vehicle size maintain service quality and efficiency goals.

Three vehicle types were studied – small 30-foot buses, standard 40-foot buses, and large 60-foot articulated buses. All are "heavy-duty" transit buses designed for stop-and-go transit work. Basic assumptions for these vehicle types are shown below.

Table 1: Vehicle Types Studied

Name	Length	Type	Capacity (seated + standing)	Fuel Use[1]	Purchase Cost [2]	Operating Cost (per hr)
Small	30'	HD	27+10	90%	$295,000	$97.25
Standard	40'	HD	35+20	---	$425,000	$97.95
Large	60'	HD Artic.	54+25	133%	$665,000	$108.82

[1] Fuel use is relative to a standard 40-foot bus. Actual fuel use depends on vehicle age, operating conditions, and whether or not it is a hybrid.
[2] Purchase cost is based on the median price for a New Flyer non-hybrid vehicle of the size shown.
[3] Life cycle costs include the purchase price and 12 years of operation at an average of about 2,080 hours per year, plus three years at 250 hours per year, with an inflation rate of 3%.

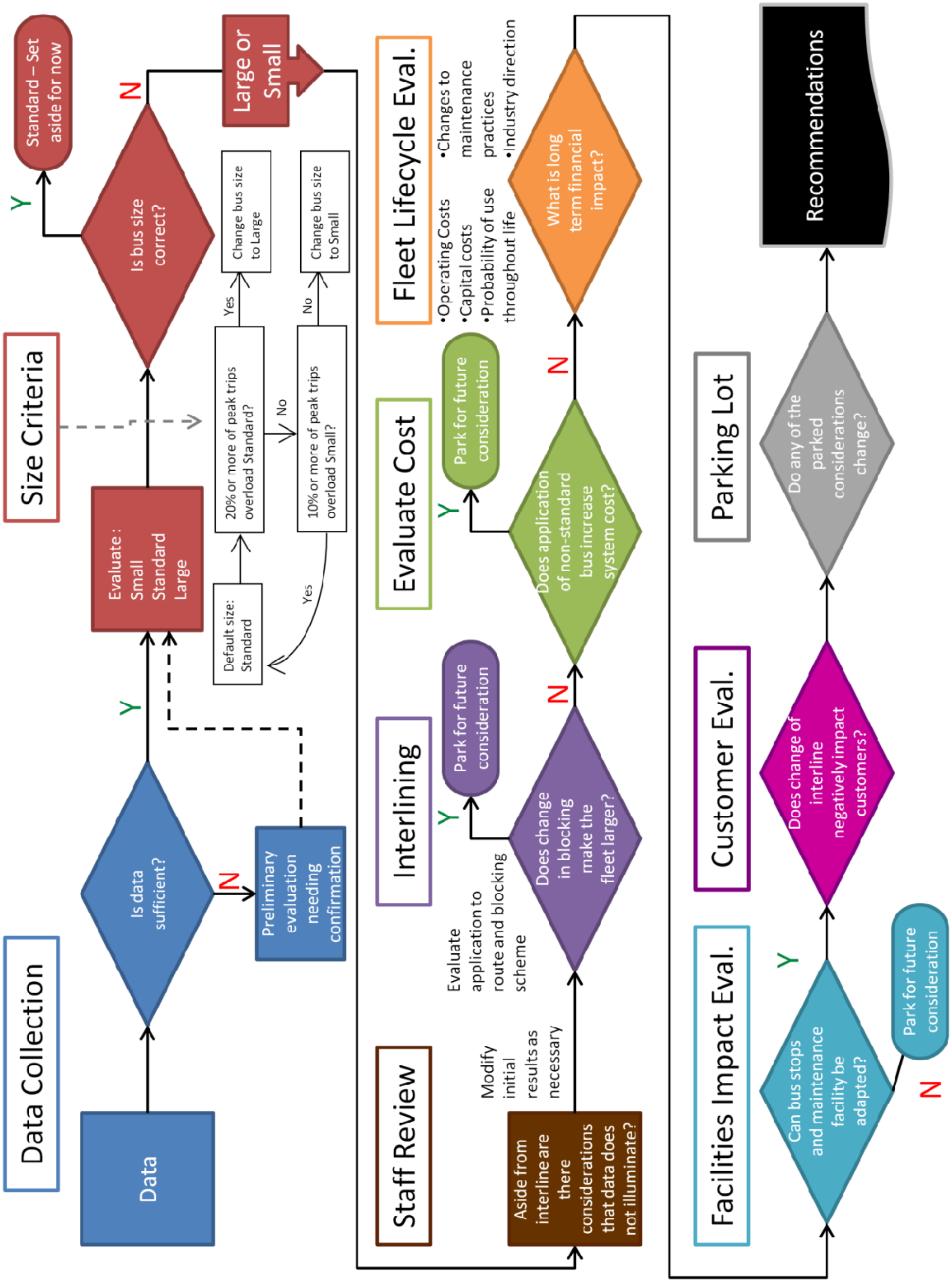
Figure 6: Examples of Vehicle Types Studied

Heavy-Duty Small Bus

Heavy-Duty Standard Bus

Heavy-Duty Large Articulated Bus

Figure 7: Bus Size Study Decision Tree



3 BUS LOADING ANALYSIS

DATA COLLECTION AND ANALYSIS

In order to determine which routes may be appropriate candidates for larger or smaller buses, onboard load screenline observations were conducted. Routes that operate in the peak were observed, but those that only operate at off-peak times were not because any bus size decision must consider the needs of the system during peak periods. Even if a route is well suited for small buses during off peak periods, small buses cannot be deployed unless they can be used during peak periods as well, when the entire fleet must be deployed (less spares)

- Surveyors were positioned at the stop locations shown in Figure 10. These stops were selected as locations where routes are likely to have their maximum passenger loads.
- Surveyors were instructed to observe each bus as it arrived at the stop and record the number of people on board. At transfer points where buses switch from one route to another, surveyors recorded the incoming load as well as the outgoing load. In cases that the bus was too full to count the number of people on board the bus, surveyors were instructed to classify the bus in one of two categories:
- **Standing Load:** Enough people standing to make it difficult to count the exact number, but the bus is not completely full (see Figure 8 for an example). In cases like this, the load was assumed to be 45 passengers.
- **Crush Load:** Bus is completely full (see Figure 8 for an example). In cases like this, the load was assumed to be 55 passengers.
- Regular bus stops were observed on two separate days in the morning peak (7:30 a.m. to 9:00 a.m.) or the afternoon peak (3:30 p.m. to 5:00 p.m.), depending on the direction of buses they serve. Stops serving buses traveling towards Downtown and the UW Campus were observed in the morning peak, and buses traveling away from Downtown and the UW Campus were observed in the afternoon peak. Transfer points were observed in both the morning and afternoon periods. Campus locations serving Route 80 were observed from 8:00 a.m. to 5:00 p.m. to capture the high loads that occur during class change times.
- Observations were conducted on March 6, March 7, April 9, and April 10, 2013.

Figure 8: Bus Load Examples

Seated Load

Standing Load

Crush Load

Typically, about 20 to 60 individual trips were observed for each route. After collecting the data, the observations were entered into an electronic database and summarized to identify maximum loads for each route at the direction, trip, and day level. For each trip, up to four observations were typically made (at transfer points as well at each end of downtown). Only the maximum of these observations was used for the load of that trip. For example, Route 4 runs every half hour between the South Transfer Point and North Transfer Point. The route was observed on two separate days at three locations: South Transfer Point, Mills & Dayton, and North Transfer Point. In the direction towards the South Transfer Point, the 4:00 p.m. trip had a maximum observed load of 49 on the first day and 32 on the second day. This analysis was conducted for each trip in each direction on every route. Figure 11 illustrates how the maximum load was selected for each trip.

Some routes in the Metro system act as route groups, operating in one direction as one route and the other direction as a different route. These routes were grouped together because it is not possible to separate them. As an example, Route 44 travels from Fitchburg to the UW in the morning, then becomes Route 48 for its return trip to Fitchburg. The route groups include Routes 11/12, 28/56/57, 37/38, 44/48, and 71/74.

Figure 9: Route 28/56/57 Group

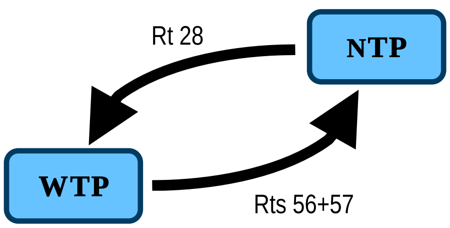


Figure 10: Load Observation Locations

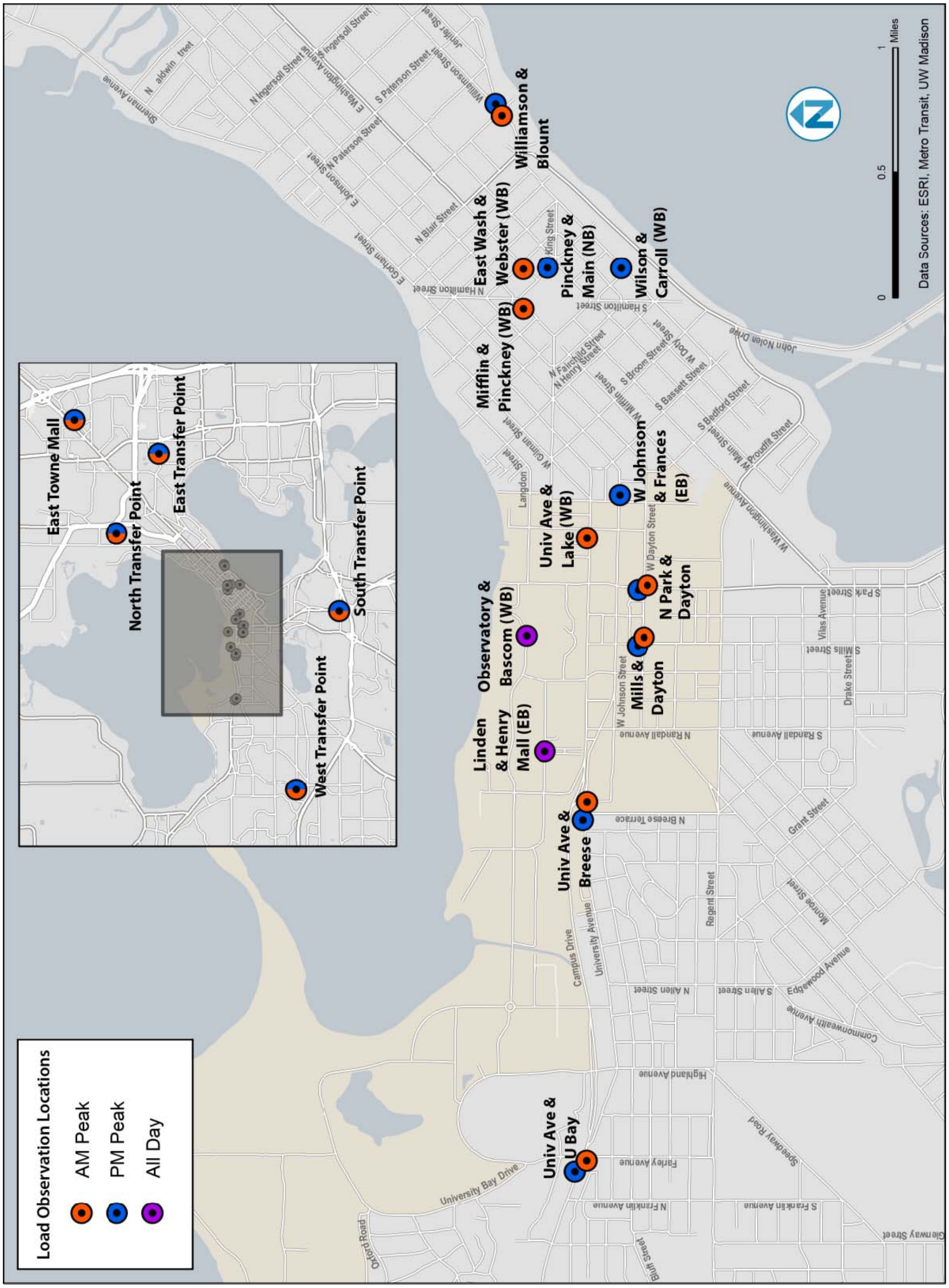
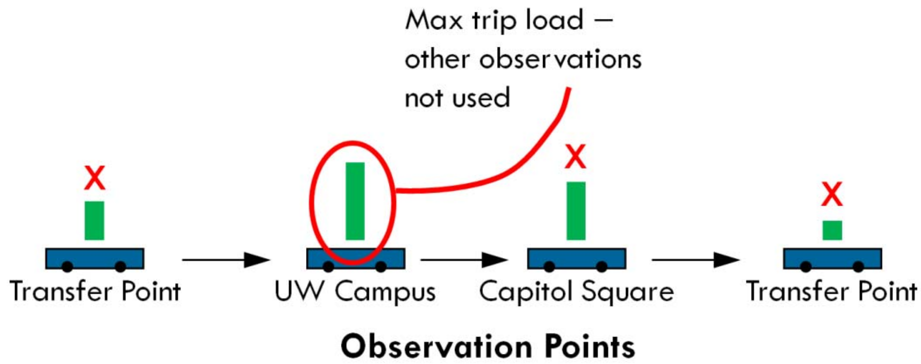


Figure 11: Maximum Load Selection



After determining the maximum observed load by day for each trip on each route, the observed loads were aggregated into 5 passenger increments (for example 1-5 passengers, 6-10 passengers, etc.) and the percentage of observations in each increment was calculated. In addition, the mean max load was calculated. This process is illustrated in figures 12 and 13.

Figure 12: Observed Loads on Route 4 4:00 p.m. Trip Towards South Transfer Point

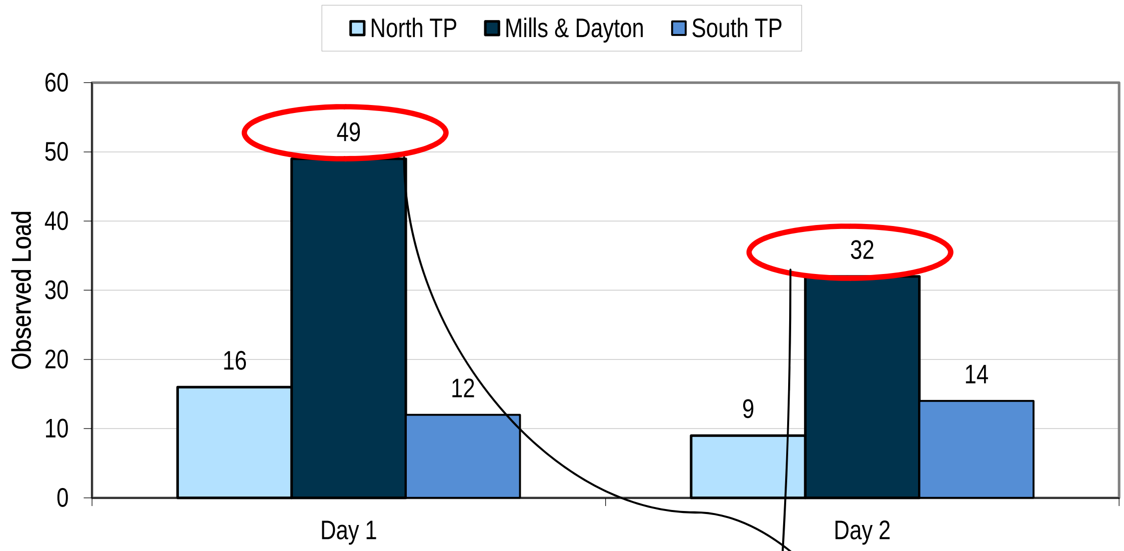
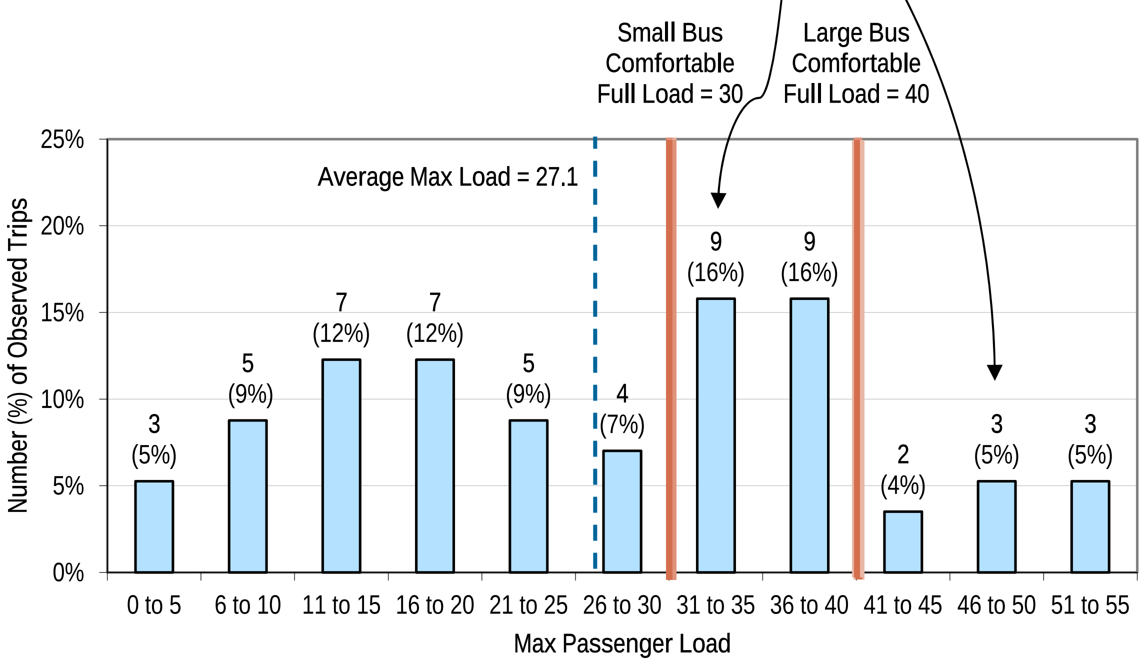
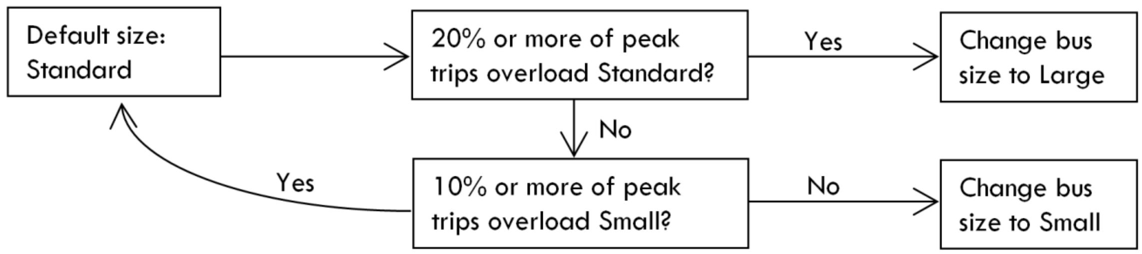


Figure 13: Percentage of Observed Trips by Max Load on Route 4



After compiling the trip loads for each route, size criteria were applied to the data to output preliminary findings. The size criteria include not having more than 20% of trips beyond a "comfortable full load" for a standard bus or more than 10% of trips beyond a comfortable full load for a small bus. The more stringent criterion of exceeding the comfortable load on a small bus is based on not having a second door for passengers to exit, as more than a few standees will cause significant circulation problems.

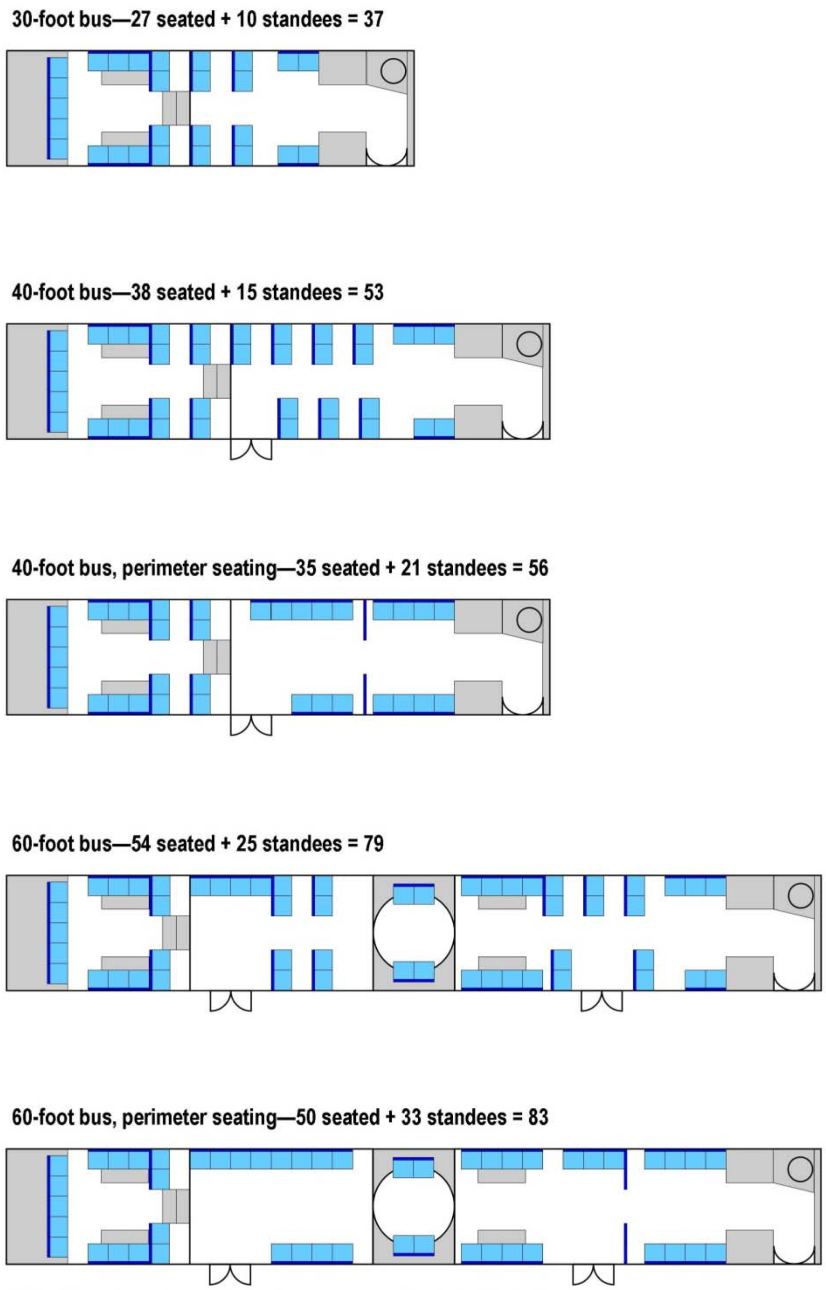
Figure 14: Bus Size Decision Chart



Comfortable loads were defined as a bus having a few more people than seats – 30 passengers for a 30-foot bus and 40 passengers for a 40-foot bus. In most cases, these loads would have a few empty seats and five to ten standees. The bus is "full" but passengers can generally circulate. More people could physically fit on the bus, but when loads approach 50 or more for a 40-foot bus, conditions are cramped and uncomfortable for standees. This methodology implies that a significant number of trips should be regularly overloaded to increase the bus size – it does not design for the "peak of the peak", which would result in an excessive vehicle size for all but one or two trips and a very short distance.

Typical bus layouts are shown below in Figure 15.

Figure 15: Example Bus Layouts



Note: These layouts and dimensions are approximate for illustrative purposes. Actual seating layouts vary and the capacity for standees is approximate.

Metro executed the August 2013 service change shortly after the observations were done, restructuring Route 10, adding Routes 31, 33, and 35, and making several other changes. Perhaps most importantly, most of the "extra" buses previously deployed as overload trips on Routes 2, 14, and 15, were codified as Route 10 and added to the Ride Guide. The August 2013 service change is not expected to have major impacts on the Bus Size Study with a few exceptions:

- New Route 31 may be a candidate for a small bus.
- The revision to Route 15, bypassing Sheboygan Avenue on peak-period trips, may reduce its need for extra capacity. However, those passengers have likely shifted to other routes, maintaining the need for additional capacity in the University Avenue corridor.
- Routes 71 and 72 began using an express stop pattern on University Avenue, alleviating some overcrowding problems.

As is the case for every transit system of this size, Metro makes service changes on a regular basis for a variety of reasons, such as responding to budget changes and serving its users better. If Metro decides to deploy smaller or larger buses in its fleet in the future, service changes that occur after this study is complete may lead to significantly modified routes that will need to be evaluated again to determine if they are good candidates for large or small buses.

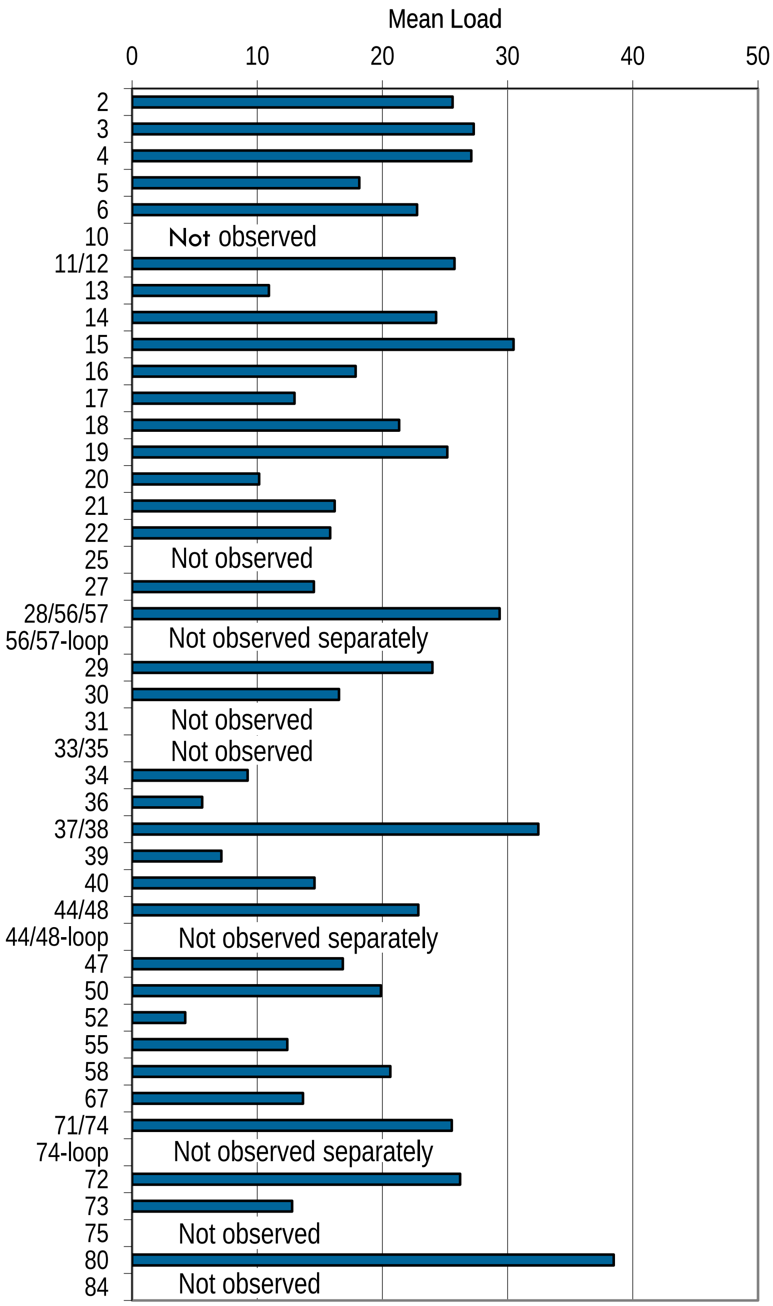
PRELIMINARY RESULTS

Preliminary results for each route after applying the screening criteria are presented in Table 2 on page 3-10, which includes the number of observations, mean max load, percent exceeding a comfortable full load on a small bus and standard bus, and the preliminary size result.

Table 2: Preliminary Results: Main-Line Routes Operating During Peak Periods

Route	Number of Observations	Mean Max Load	% Exceeding Small Full Load	% Exceeding Standard Full Load	Preliminary Size Result
2	68	26	43%	15%	Standard
3	44	27	48%	36%	Large
4	57	27	46%	14%	Standard
5	44	18	9%	0%	Small
6	85	23	33%	14%	Standard
10	Route was introduced in August 2013 and thus was not observed during the data collection.				
11/12	34	26	38%	12%	Standard
13	31	11	3%	0%	Small
14	41	24	44%	12%	Standard
15	45	30	60%	38%	Large
16	42	18	7%	0%	Small
17	46	13	4%	0%	Small
18	39	21	10%	0%	Standard
19	28	25	36%	25%	Large
20	39	10	5%	0%	Small
21	30	16	10%	10%	Standard
22	33	16	12%	6%	Standard
25	Route was not observed during data collection.				
27	18	15	11%	6%	Standard
28/56/57	93	29	58%	40%	Large
29	6	24	33%	0%	Standard
30	39	17	13%	8%	Standard
31	Route 31 was introduced in August 2013 and thus was not observed during the data collection.				
33/35	Revised and new service in August 2013.				
34	17	9	0%	0%	Small
36	15	6	0%	0%	Small
37/38	70	32	63%	43%	Large
39	15	7	0%	0%	Small
40	21	15	5%	0%	Small
44/48	25	23	36%	20%	Large
47	19	17	21%	0%	Standard
50	16	20	25%	19%	Standard
52	18	4	0%	0%	Small
55	5	12	0%	0%	Small
58	22	21	27%	23%	Large
67	32	14	13%	0%	Standard
71/74	13	26	46%	23%	Large
72	23	26	43%	26%	Large
73	19	13	5%	0%	Small
75	Route was not observed during data collection.				
80	171	38	68%	55%	Large
84	Not observed. Assumed to have similar characteristics to Route 80.				

Figure 16: Observed Mean Load by Route



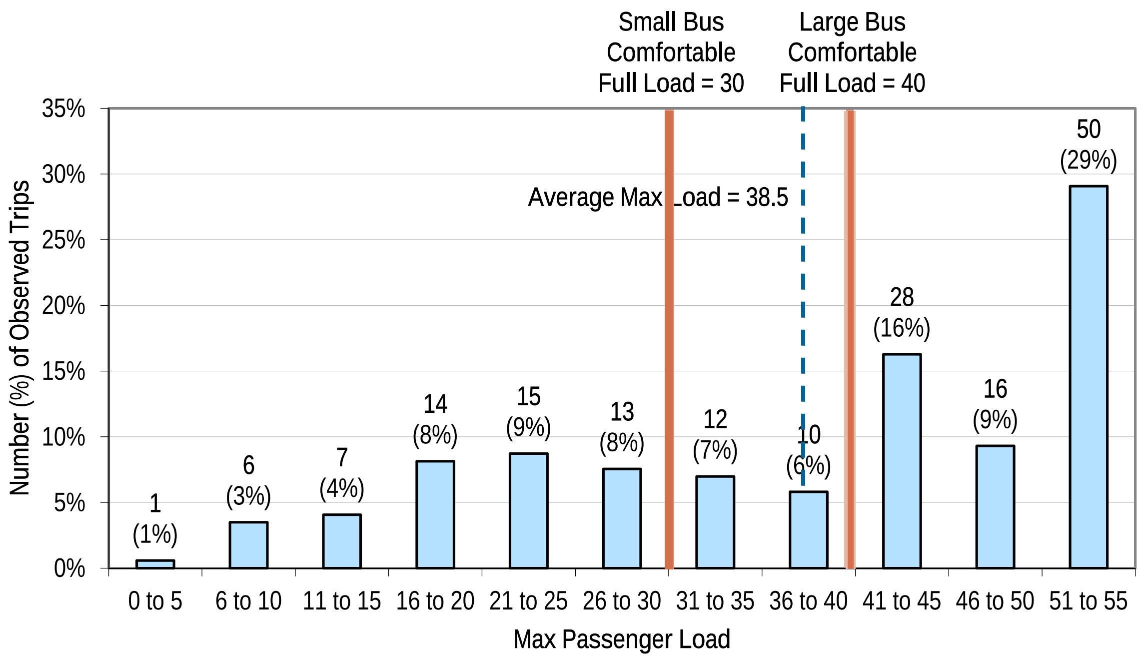
Size Evaluation Examples

The following are examples of how the size criteria were applied to determine which size bus should be deployed on a route.

Large Bus Example

Route 80 is a candidate for large buses due to the high percentage of standing and crush loads (55% of observations above 40 passengers).

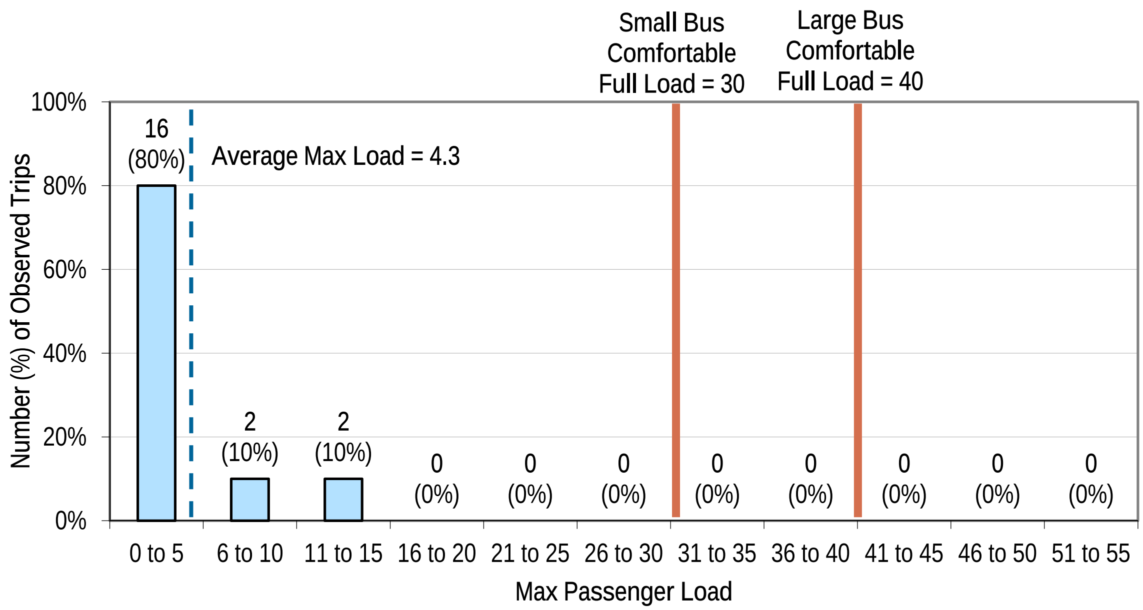
Figure 17: Percentage of Observed Trips by Max Passenger Load on Route 80



Small Bus Example

Route 52 is a candidate for small buses due to the fact that no loads above 15 were observed.

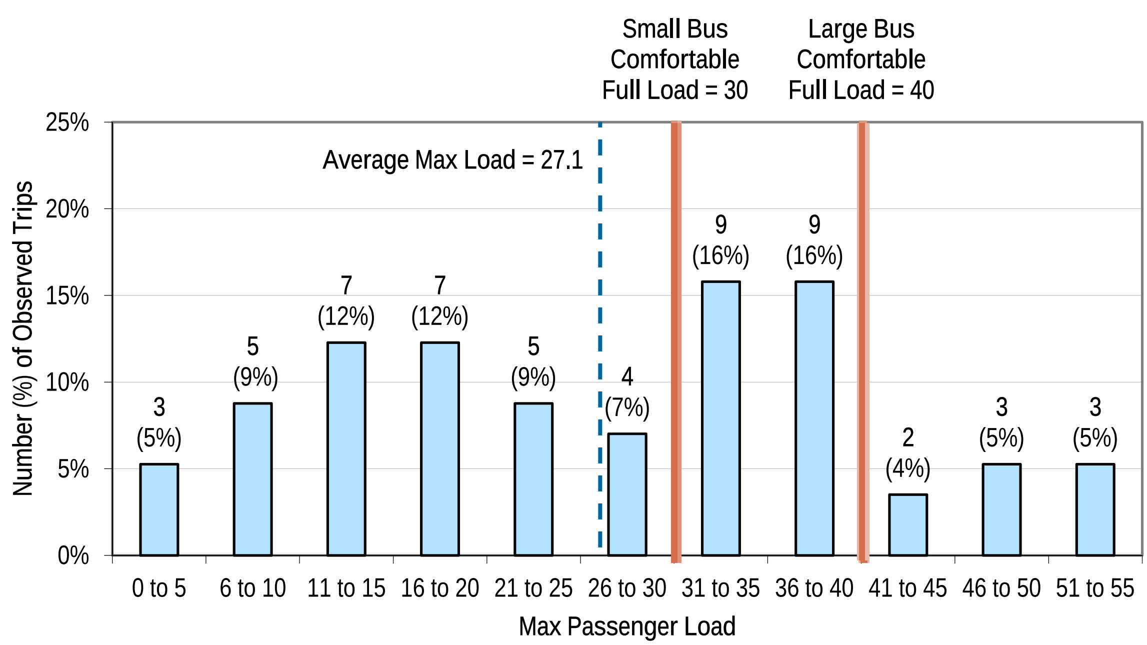
Figure 18: Percentage of Observed Trips by Max Passenger Load on Route 52



Standard Bus Examples

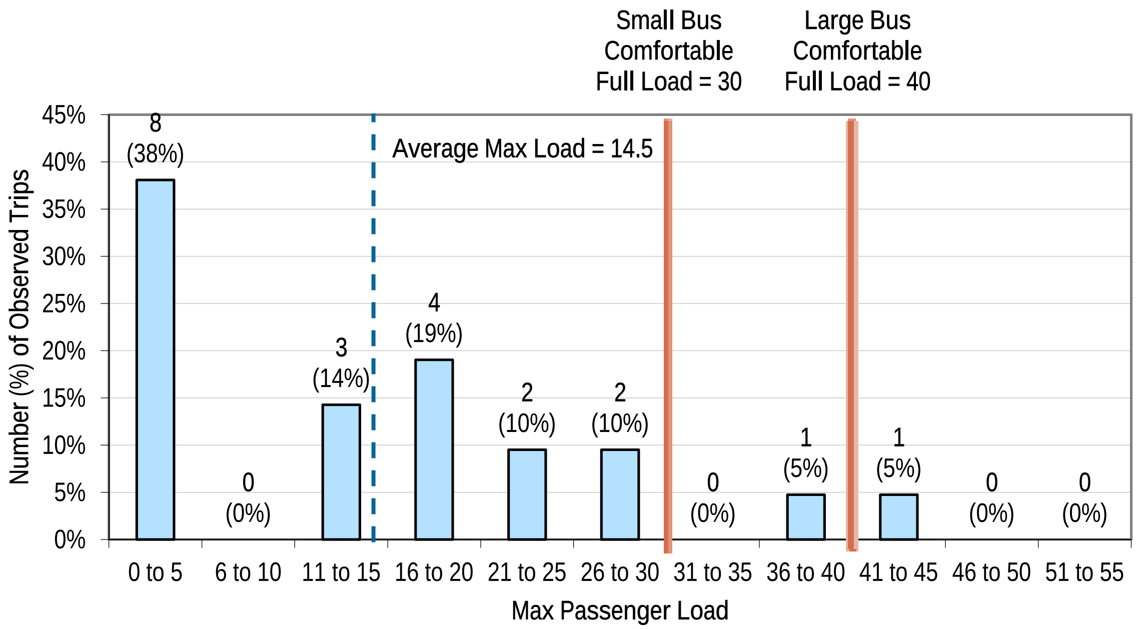
Route 4 is a candidate for a standard bus due to only 14% of loads above 40 (comfortable capacity on a standard bus).

Figure 19: Percentage of Observed Trips by Max Passenger Load on Route 4



Route 27 is a candidate for a standard bus, rather than a small due to the peaking characteristics. The route has a low average at 15 boardings, but 10% loads are well above small bus capacity at 36 plus boardings. The high frequency of loads in the 0 to 5 range implies that Route 27 carries most passengers in the peak direction – towards the UW in the morning and towards the North Transfer Point in the evening.

Figure 20: Percentage of Observed Trips by Max Passenger Load on Route 27



4 MPO AND METRO STAFF REVIEW AND INTERLINE ANALYSIS

MPO AND METRO STAFF REVIEW

The project stage following the preliminary bus size analysis was a staff review. The data collection described above is limited in that it took a snap shot of loads during peak periods over the course of a few days. Sufficient resources are not available to get a comprehensive look at how loads on buses go up and down throughout the trip, throughout the day, and throughout the year. For that insight, the study relied on Metro staff input to adjust the results obtained during the preliminary analysis. Further, several structural changes were made in the August 2013 service change, introducing three new routes in east Madison and substantial changes in the crowded University Avenue corridor, and these changes needed to be taken into account. In the future, Metro may use Automated Passenger Counters (APCs) to provide more consistent and accurate passenger load data.

Overload Reports

Metro keeps detailed records of overloads that are reported by operators, and these records were considered as part of the staff review As shown in the charts below, records since the August 2013 service change show overloads primarily on core east-west service (Routes 2, 6, and 28), and during peak periods.

Figure 21: Reported Overloads by Route, Aug 27 – Nov 21, 2013

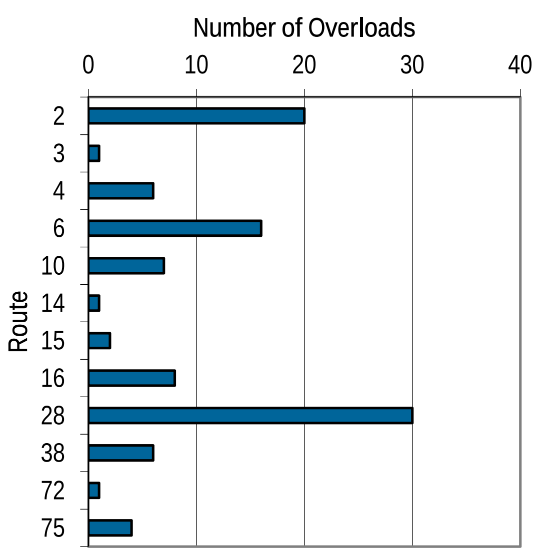


Figure 22: Reported Overloads by Day, Aug 27 – Nov 21, 2013

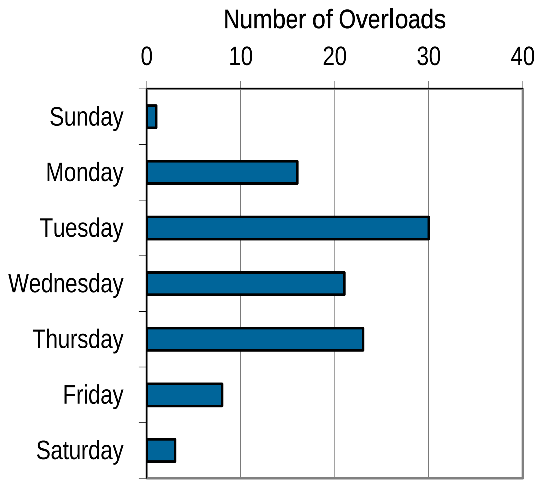
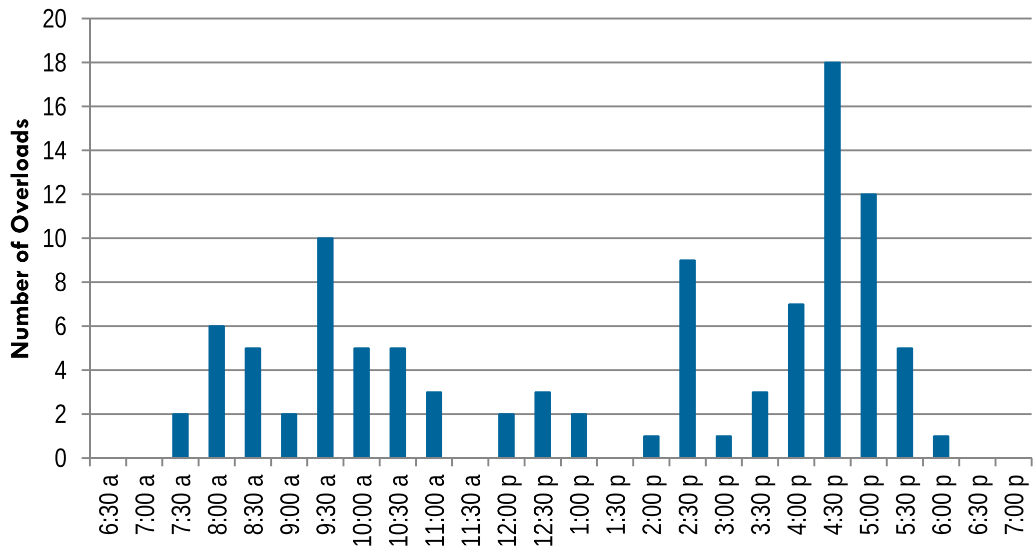


Figure 23: Reported Overloads by Time, Aug 27 – Nov 21, 2013



Bus Size Revisions

Several changes were made to the initial bus size results to form the final bus size recommendations. These changes can be seen in Table 3 on page 4-12 between the "Preliminary Results" and "Screened Results" columns. Overall, eight routes had their bus size increased and six had their bus size decreased. The rationale for these changes, as well as the effect a bus size change would have on interlining, needed route restructures to accommodate the bus size, and other information, is summarized for selected routes below.

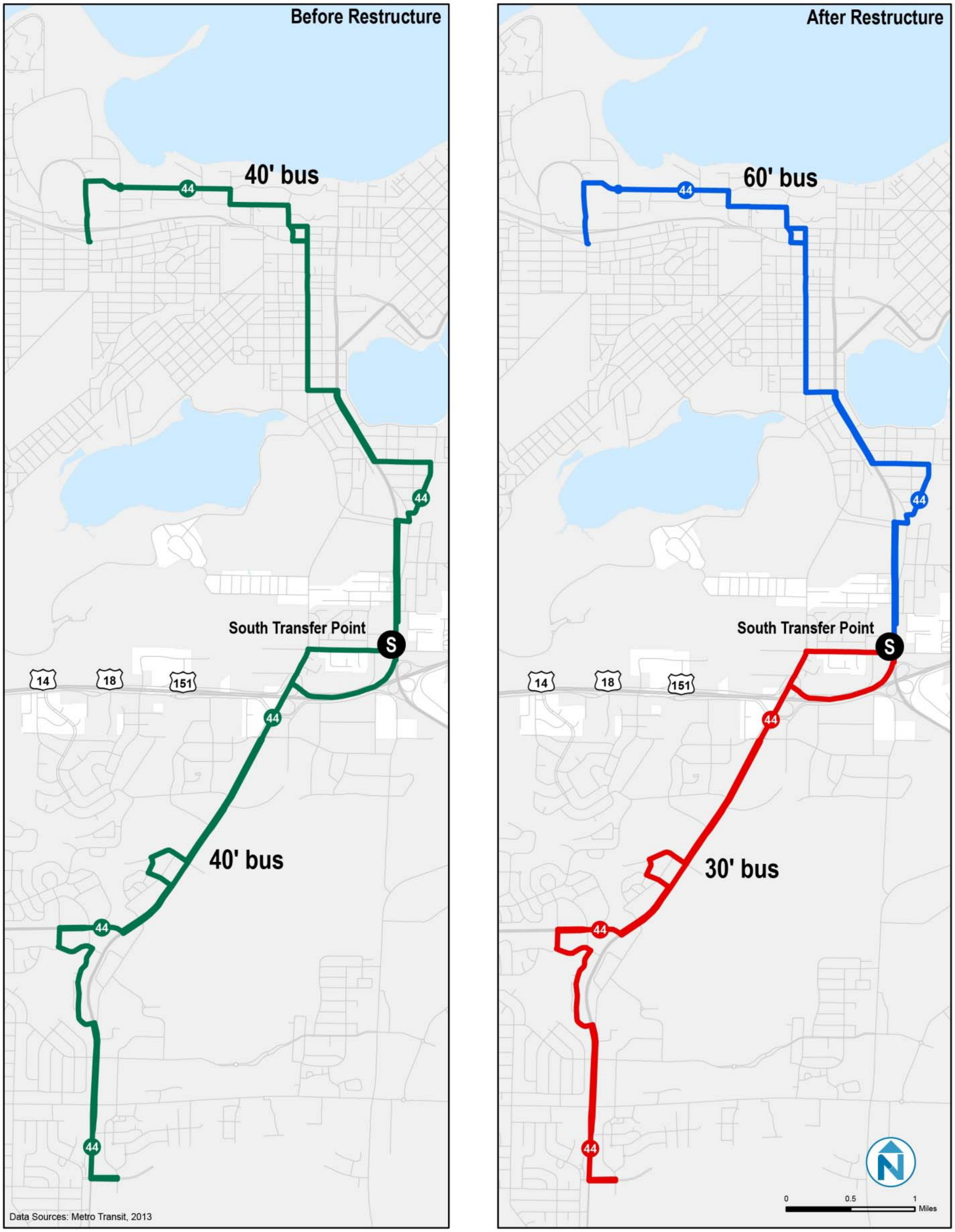
One component of the analysis was identifying long routes for their potential to use different sized buses on different portions of their routes. This would require a restructure. Passengers would no longer be able to use one route to commute from the periphery of the service area to central Madison as they do today; they would transfer from a smaller bus to a larger bus at some point in their trip, likely at a transfer point. This concept is illustrated using Route 44 as an example in Figure 24 below.

Metro's route structure is extremely complex with significant interlining between routes. An interline analysis was conducted for routes where the vehicle size would change to a non-standard size (large or small). Most routes in the Metro Transit system are interlined with one or more other routes, meaning that when a vehicle completes a trip on one route, it may switch to a different route for its next trip. If the vehicle size on one route in an interline pair is changed, but the other is not, then the routes can no longer be interlined together. Depending on the routes' schedules, it may require a larger number of vehicles to serve the routes separately than if they were interlined together, which would make the overall fleet size larger and increase costs.

It should be noted that Metro Transit's schedules are very complex, which makes it difficult to conduct the analysis on some routes. Aside from the complexity, the interlining is quite dynamic. In a few cases the combinations that existed when the study began were modified six months later. More than anything, this suggests one of the challenges of working with a mixed fleet. The challenge of ensuring proper and efficient deployment is a constant effort, particularly in a system with the complexities of Madison's.

This section also includes a "confidence level" indicator for each route where the vehicle size would change to a non-standard size (large or small). In cases where switching to a different size bus would be relatively straightforward and interlining impacts would be minor, the confidence level is high. In cases where interlining impacts would be major, the confidence level is set to medium.

Figure 24: Potential Route 44 Restructure to Use Large & Small Buses



Route 2

Preliminary Bus Size: Standard

Recommended Bus Size: Large

Interline Impacts: Minor

Confidence Level: High

Discussion: The University Avenue corridor is served by many routes and is severely over capacity. On any given day, loads shift between routes substantially depending on random arrival patterns. Route 2 also has many extra buses and Route 10 trips to handle passenger volumes. Upgrading buses in this corridor to large buses may reduce the need for extra buses, reducing costs.

Route 2 could be re-blocked alone to operate with 4 vehicles on the standard variant. Additional vehicles are used in the peak on short trips, which would likely need to be interlined with other routes or use standards to maintain efficiency. Route 2 is currently interlined with Routes 20, 50, and 51. These interlines will need to be broken. The simplest solution would be to interline Routes 50 and 51 together and Route 20 could operate alone – although this would not create systemic inefficiencies, riders would no longer have a one-seat ride or guaranteed transfer and some additional deadheading may be required.

Route 3

Preliminary Bus Size: Large

Recommended Bus Size: Standard

Discussion: Loads are expected to peak where Route 3 overlaps with Route 38 and routes west of the UW campus, and overcrowding is better handled with extra buses.

Route 5

Preliminary Bus Size: Small

Recommended Bus Size: Standard

Discussion: This route is considered core service and should remain a standard bus to maintain flexibility.

Route 13

Preliminary Bus Size: Small

Recommended Bus Size: Small

Interline Impacts: Minor

Confidence Level: High

Discussion: This route is not currently interlined with any other routes on weekdays, so changing the vehicle size in the future would not impact other routes. It is interlined with Route 18 on weekends which would likely be incompatible with a small bus; Route 18 could operate alone or possibly with other routes such as Routes 5 and 32 on weekends.

Route 15

Preliminary Bus Size: Large

Recommended Bus Size: Large

Interline Impacts: Minor

Confidence Level: High

Discussion: Route 15 is currently interlined with Routes 14, 33, and 35. To accommodate large buses, it would need to be separated from Routes 33 and 35, which would be interlined with each other. Although this would not necessarily create systemic inefficiencies, riders would no longer have a one-seat ride or guaranteed transfer and some additional deadheading may be required. Routes 14 and 15 may be able to be separated from each other; however, some Route 14 trips are also very heavy, so it is assumed that some Route 14 trips may be suitable for large buses from Route 15 and some Route 15 trips may, as a result, be standard buses from Route 14. Similarly, Route 15 has additional peak-direction service, and some trips may continue operating on their current blocks with regular vehicles. Route 15 is typically heavily loaded for the majority of its route but has a long tail in west Madison; this may result in some inefficiency with a large bus with few passengers.

Route 16

Preliminary Bus Size: Small

Recommended Bus Size: Standard

Discussion: Route 16 has consistently high loads all day, including school-related extra trippers.

Route 17

Preliminary Bus Size: Small

Recommended Bus Size: Small

Interline Impacts: Minor

Confidence Level: High

Discussion: Route 17 could be blocked alone or with Routes 34 and/or 39, which it is currently interlined with. Route 22 is currently blocked with Routes 17, 34, and 39 and would need to be re-blocked with a different set of routes or operate alone.

Route 19

Preliminary Bus Size: Large

Recommended Bus Size: Standard

Discussion: The route is long with a meandering tail that is not appropriate for large buses.

Route 20

Preliminary Bus Size: Small

Recommended Bus Size: Standard

Discussion: In the data collection, the two trips that overloaded a small bus had estimated loads of about 40, which is beyond the physical capacity of a small bus.

Routes 28, 56, and 57

Preliminary Bus Size: Large

Recommended Bus Size: Large for mainline, Standard for section south of the West Transfer Point

Interline Impacts: Minor

Confidence Level: High

Discussion: Route 28 is interlined with two reverse-direction routes, Routes 56 and 57. Routes 56 and 57 are bordering on qualifying for large buses; further, they are part of the University Avenue corridor which, in general, experiences severe capacity problems. The section of Routes 56 and 57 south of the West Transfer Point is not appropriate for a large bus because of the lower ridership volumes and residential nature, so those parts would need to be removed from the Route 28/56/57 system and operated with standard buses alone or combined with other service. The remaining main-line route group would use large buses.

Route 31

Bus Size Revision

Preliminary Bus Size: No Data

Recommended Bus Size: Small

Interline Impacts: Minor

Confidence Level: Medium

Discussion: This route was introduced in August 2013, so there is limited data. Its loads are assumed to be compatible with a small bus, but the confidence level is medium because data have not been collected for this route. Route 31 operates alone and has no interlining concerns.

Routes 33 and 35

Preliminary Bus Size: No Data

Recommended Bus Size: Standard

Discussion: Route 33, as observed in the loading analysis, was discontinued in August 2013. New Route 33 operates only at peak periods in an area that previously had little to no transit service. Although the ridership for Route 33 is unknown and may be relatively low, it cannot efficiently be blocked alone because of its 45 minute cycle time. Route 35 was created in August 2013 and so was not observed. It takes over a service area that was vacated by Route 15. Because Routes 33 and 35 both have 45 minute cycle times, they cannot efficiently be blocked alone, but it may be practical to interline them together. For that strategy to be successful, both routes would need to be able to accommodate a small bus. Routes 33 and 35 are currently interlined with Routes 14 and 15; breaking this interline would not necessarily create systemic inefficiencies but riders would no longer have a one-seat ride or guaranteed transfer and some additional deadheading may be required. For these reasons it is recommended that Routes 33 and 35 be re-evaluated in the future to determine if the level of demand warrants a small bus.

Routes 34 and 39

Bus Size Revision

Preliminary Bus Size: Small

Recommended Bus Size: Small

Interline Impacts: Minor

Confidence Level: High

Discussion: These routes may be appropriate for a small bus. They are currently interlined with Route 17; that configuration could continue or they could be interlined together without Route 17.

Route 36

Preliminary Bus Size: Small

Recommended Bus Size: Standard

Interline Impacts: Major

Discussion: This route could hypothetically be interlined with Route 26 during off peak periods using one vehicle. These routes are currently interlined with Route 30, which cannot efficiently be blocked alone. The bus size recommendation for Route 30 is a standard size bus. Routes 26 and 36 operating together would necessitate 20 or 40 minute headways because of their 20 minute cycle lengths, and Route 30 operating alone would require 20 or 40 minute headways because of its 40 minute cycle length. The net result would be a substantial increase in operating costs because the rotation would increase from 2 buses to 3 buses, and potentially longer transfers because of the lost timed transfers with 30 to 60 minute headways on the rest of the system. Due to these issues associated with interlining, it is recommended that Route 30 continue to operate with standard buses.

Routes 37 and 38

Preliminary Bus Size: Large

Recommended Bus Size: Large

Interline Impacts: Minor

Confidence Level: High

Discussion: Route 38 is interlined with a reverse-direction route, Route 37. Route 38 is typically heavily loaded through the isthmus and UW campus areas but has a long tail in east Madison; this may result in some inefficiencies with a large bus with few passengers.

Route 40

Preliminary Bus Size: Small

Recommended Bus Size: Standard

Discussion: 9.5% of trips would have overloaded a small bus, which rounds up to 10%, crossing the threshold.

Routes 44 and 48

Preliminary Bus Size: Large

Recommended Bus Size: Large north of the South Transfer Point, Small south of the South Transfer Point

Interline Impacts: Major

Confidence Level: Medium

Discussion: Route 44 is interlined with a reverse-direction route, Route 48. The section of Routes 44 and 48 south of the South Transfer Point is not appropriate for a large bus because of the lower ridership volumes and residential nature. The loop south of the South Transfer Point would be removed from the rest of the route and operated with small buses; the remaining main-line route group would use large buses. This break creates a few interlining problems because the north and south sections each have cycle times of about 45 minutes. The restructured routes may need to be shortened, lengthened, or interlined with other compatible routes. The confidence level is set to medium due to these issues.

Route 52

Preliminary Bus Size: Small

Recommended Bus Size: Small

Interline Impacts: Minor

Confidence Level: High

Discussion: Route 52 is currently interlined with Routes 11 and 12 during peak periods and Route 73 at other times. During peak periods, it is likely possible to break the interline with Routes 11 and 12 and operate Route 52 alone. Although this would not necessarily create systemic inefficiencies, riders would no longer have a one-seat ride or guaranteed transfer and some additional deadheading may be required. During mid-days, it may be practical to continue interlining Routes 52 and 73.

Route 55

Preliminary Bus Size: Small

Recommended Bus Size: Standard

Discussion: High volume peak trips have been reported, and growth at Epic is planned.

Route 58

Preliminary Bus Size: Large

Recommended Bus Size: Standard

Discussion: The route is long with a meandering tail that is not appropriate for large buses.

Routes 71 and 74

Preliminary Bus Size: Large

Recommended Bus Size: Large from the Capitol Square to the Middleton Transfer Point, Small from the Middleton Transfer Point to the west

Interline Impacts: Major

Confidence Level: Medium for mainline portion of routes.

Discussion: The loop west of the Middleton Transfer Point to the Middleton Business Park would be removed from the rest of the route group and operated with a small bus; the main-line for Routes 71 and 74 would use large buses.

Route 71 is interlined with Routes 70, 73, and 74, with Route 74 providing the primary reverse-direction service. If the portion of Route 74 west of the Middleton Transfer Point were to be separated from Route 74 and the Route 74 schedule adjusted, they could be interlined in during peak hours. The effects of this action on the blocking of other routes will need to be examined in more detail.

Route 74 west of the Middleton Transfer Point has an irregular cycle time of about 20 minutes. In order to operate Route 74 during peak periods, it may need to be shortened, lengthened, or interlined with other routes, such as Route 73.

Due to the need to restructure this route to accommodate different size buses, the confidence level for the 71/74 mainline is set to high, and for the Route 74 loop west of the Middleton Transfer Point it is set to medium.

Route 72

Preliminary Bus Size: Large

Recommended Bus Size: Large

Interline Impacts: Minor

Confidence Level: High

Discussion: Route 72 is interlined with Routes 70, 73, and 74. However because it provides some reverse-direction service in the peak, it could be re-blocked alone, with the exception of two peak-direction trips. The effects of this action on the blocking of other routes will need to be examined in more detail.

Route 73

Preliminary Bus Size: Small

Recommended Bus Size: Small

Interline Impacts: Major

Confidence Level: Medium

Discussion: Route 73 is extensively interlined with Routes 70, 71, 72, and 74 during peak periods. It has an irregular cycle time of about 75 minutes. In order to operate Route 73 during peak periods, it may need to be shortened, lengthened, or interlined with other routes, such as Route 74 west of the Middleton Transfer Point. Due to these issues, the confidence level is set to medium.

Route 75

Recommended Bus Size: Standard

Discussion: Route 75 was not observed during the study because its routing does not pass any of the observation points. Given the long distance nature of most Route 75 passenger trips, passenger loads can be inferred with electronic boarding data. Significant reported load on Route 75 indicate that it would likely be a good candidate for a large bus; however, it is a peak-only route with only six round trips per day.

Routes 80 and 84

Preliminary Bus Size: Large

Recommended Bus Size: Large

Interline Impacts: Minor

Confidence Level: High

Discussion: Route 80 is currently blocked alone and requires 7 vehicles. Along with Route 84, a PM peak period express service using 1 vehicle, this route should be prioritized for conversion to large vehicles since in 2012 the two routes carried about 12% of Metro's total ridership. Route 80 is not interlined with other routes. During peak periods, Route 80 service is reduced slightly because of additional commuter service flowing through campus, freeing a large bus for Route 84.

SUMMARY

Table 3 below presents the final bus size results after the staff review and interline analysis.

Table 3: Final Results: Main-Line Routes Operating During Peak Periods`

Route	Preliminary Results	Final Recommendations	Confidence Level	Buses in Rotation
2	Standard	**Large**	High	4 *
3	Large	**Standard**		4
4	Standard	Standard		4
5	Small	**Standard**		3
6	Standard	Standard		5
10		**Standard**		4-5
11/12	Standard	Standard		4
13	Small	Small	High	2
14	Standard	Standard		4
15	Large	Large	High	5
16	Small	**Standard**		3
17	Small	Small	High	1
18	Standard	Standard		2
19	Large	**Standard**		3
20	Small	**Standard**		2
21	Standard	Standard		2
22	Standard	Standard		2
25		**Standard**		Varies
27	Standard	Standard		2
28/56/57	Large	Large	High	8
56/57-loop		**Standard**		3
29	Standard	Standard		Varies
30	Standard	Standard		1.4
31		**Small**	Medium	1
33/35		**Standard**		3
34	Small	Small	High	0.5
36	Small	**Standard**		0.6
37/38	Large	Large	High	8
39	Small	Small	High	0.5
40	Small	**Standard**		1
44/48-main	Large	Large	Medium	1.5
44/48-loop		**Small**	Medium	1.5
47	Standard	Standard		2
50	Standard	Standard		1
52	Small	Small	High	1
55	Small	**Standard**		2
58	Large	**Standard**		3
67	Standard	Standard		2
71/74-main	Large	Large	High	3
74-loop		**Small**	Medium	0.5
72	Large	Large	High	3
73	Small	Small	Medium	2.5
75		**Standard**		2
80	Large	Large	High	7
84		**Large**	High	0**

* Route 2 uses an additional three vehicles for peak period service, but these vehicles are envisioned to remain as standard buses
** Route 84 uses one bus during the PM peak. At this time, Route 80 uses one less bus.
Note: Bold blue text indicates that the recommended bus size changed between the preliminary results and final recommendations.

Summary of Potential Small Bus Routes

Table 4 lists the routes that are suitable for small bus deployment and the number of vehicles currently utilized to operate them during peak periods. A total of 5 routes were found to be suitable for small vehicles at this time. Converting these routes to small vehicles would require a maximum of 5 buses, which in addition to 1 spare (assuming a 20% spare vehicle need), would total 6 small vehicles. There are 4 additional routes where small buses could potentially be deployed given restructuring or additional data collection. These routes are shown under the "Potential Small Bus Routes Requiring Additional Data or Restructure" heading in the table below. If these routes utilized small buses, the small-bus fleet size would increase to 13.

Table 4: Summary of Routes Suitable for Small Buses

Route	Number of Vehicles Required
Small Bus Candidate Routes	
13	2
17	1
34	0.5 – shared with Route 39
39	0.5 – shared with Route 34
52	1
Small bus fleet	5 (6 with spares)
Potential Small Bus Routes Requiring Additional Data or Restructure	
31	1
44/48-loop	1
73	2.5
74-loop	1
Maximum conceivable small bus fleet	10-11 (13 with spares)

If a decision is reached to include small buses in the fleet, it is recommended there be at least ten buses as that is a desirable minimum number to efficiently manage in the facility and to maintain due to the costs of maintaining parts inventory for a small fleet. A smaller number could be acquired and deployed, but the inefficiencies of this deployment would very likely cancel any real or perceived benefits. These inefficiencies include increased labor costs associated with planning for, maintaining, and operating two different types of vehicles.

If the current route system were extensively restructured, a more substantial fleet of small buses could be deployed while maintaining customer-friendly capacity on lower demand routes. The trade-off is that some riders would need to transfer, thereby losing their one-seat commute of today.

Metro may well have an opportunity to consider significant restructuring of the route system in such a way that would make some of the outlying routes potentially suitable for application of small buses, such as Routes 71, 73, and 74. However, the primary goal of such a restructure should not be to fit the service to small vehicles, but to improve the efficiency of the outlying routes and maximize service to the public within Metro's available resources. If service change concepts are developed that accomplish those goals while and serving the route with a small vehicle is appropriate, that provides a new decision point for Metro and the community.

The scope of this study is focused on the overall fleet make-up of Metro. From the standpoint of optimal capital investment this must necessarily focus on peak deployment. It is highly probable that there are off-peak opportunities where deployment of smaller vehicles could both enhance the efficiency and the image of Metro. However, this would require maintaining a fleet of small buses for off-peak use only, which is not financially responsible and a practice that is unsupported by the major funding agency for bus capital, the Federal Transit Administration (FTA). Simply stated the FTA will not fund buses that are not utilized in peak periods other than a reasonable number of buses for maintenance spares, set at a maximum of 20% of peak deployment. The FTA funds bus acquisition at 80% of the total cost, but they also require that agencies follow the FTA fleet management regulations.

In the course of the decision process it should also be noted that a side benefit of smaller buses is that they use less fuel, therefore they emit fewer greenhouse gases (GHG's). While the integration and deployment discussed in this study was focused on peak periods, deployment of a fleet that emits fewer GHG's in off-peak time periods could contribute to measureable reductions in transit generated GHG's while maintaining, or even improving, community mobility. This is essentially a double win for environmental sustainability. Impacts to greenhouse gas emissions of utilizing small buses are described in more detail in the next chapter.

As vehicles in Metro's fleet age and are replaced, they generally transition from all-day work to peak only work and end their useful lives as trippers (performing only a few daily trips on school days) for Supplemental Schoolday Service. One challenge to face with small buses is finding a role for older small buses that will likely not have a role in the Supplemental Schoolday Network. These small buses may need to continue to provide main-line service throughout their useful lives, effectively exposing riders and operators to older, less reliable equipment.

Summary of Large Bus Routes

Table 5 lists the routes that are suitable for large bus deployment and the number of vehicles currently utilized to operate them during peak periods. If all of these routes were converted to large vehicles it would require that Metro acquire 48 large vehicles, which comes at a cost that is described in the costs section.

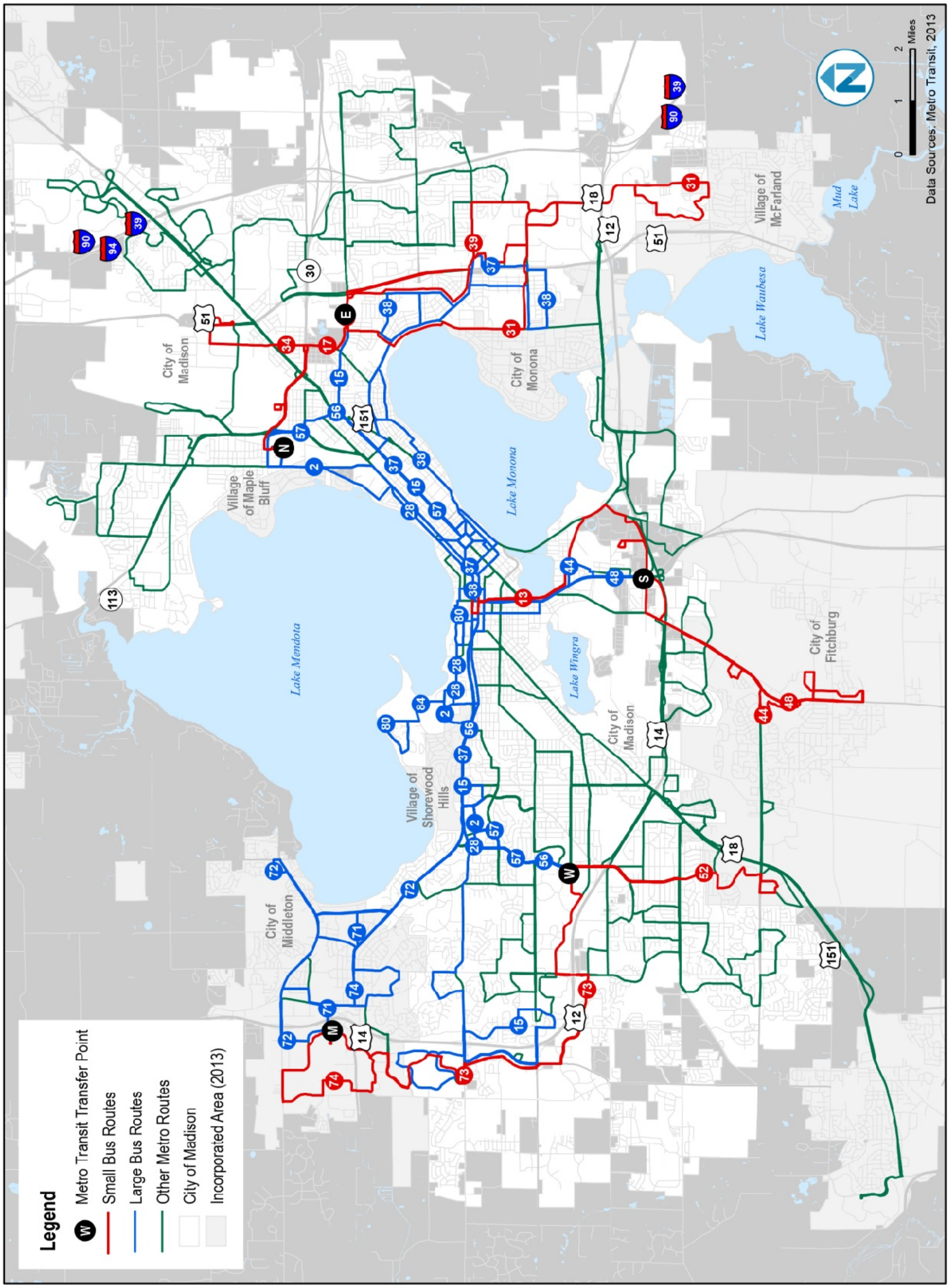
Table 5: Summary of Routes Suitable for Large Buses

Route	Number of Vehicles Required
2	4
15	5
28/56/57*	8
37/38*	8
44/48-main*	1.5
71/74-main*	3
72*	3
80/84*	7
Total	39.5 (48 with spares)

* Peak only

Several opportunities to implement large buses present themselves, primarily in Madison's east-west corridor that is constrained by geography. One challenge that presents itself is that of the 40 buses that could be used on these routes, all but about 13 are peak only. This is a problem because new buses are generally used extensively throughout the day in order to expose riders and operators to the newest and most reliable equipment. Partially for this reason, the concept of smaller fleet of large buses was developed – about 13 – that would be used for all-day service on Routes 2 and 80. Ultimately, as these vehicles age and are replaced, they would be available for other routes.

Figure 25: Small and Large Bus Routes



5 IMPACTS OF BUS SIZE CHANGES

COST ANALYSIS

Mixed Fleet Cost Analysis

Introducing new vehicle types will alter the costs associated with vehicle acquisition, operation, and maintenance over the lifetime of each type of vehicle. A review of current literature and peer agency experience was conducted to identify the expected difference in fuel efficiency, maintenance costs, and vehicle acquisition costs for small, standard, and large vehicles. Values from this assessment in addition to data regarding Metro Transit's standard vehicle costs were used to compare operating costs for the current fleet with operating costs for the fleet recommended above. This analysis compares costs on a per-bus basis, not per-rider.

Literature and Peer Agency Review

Peer agencies with mixed fleets include the Washington Metropolitan Area Transit Authority (WMATA, Washington, D.C.) and King County Metro (KCM, Seattle, WA). Additional data includes vehicle testing conducted by the Altoona Bus Research and Testing Center and reported by the Transit Cooperative Research Program and the Center for Urban Transit Research (CUTR)[1]. Only values for diesel, articulated 60-foot coaches were included in the large vehicle analysis. Small vehicles included heavy-duty diesel transit vehicles under 40-feet long and did not include cutaway vehicles. Table 6 summarizes the average cost difference between each vehicle category for fuel efficiency (in miles per gallon) and maintenance. The average change in cost for fuel efficiency and maintenance was applied to the baseline cost for standard-size vehicles in Madison's current fleet, described further in the following section.

Table 6: Operating Cost Differential for Small, Standard, and Large Vehicles

Vehicle Size	Fuel Consumption	Maintenance Cost
Small	90%	100%
Standard	100%	100%
Large	133%	143%

Metro's newer non-hybrid buses currently get about 4.3 miles per gallon (MPG) while newer hybrid buses get about 5.3 MPG (September 2013 Performance Indicators Report). Transit bus fuel efficiency is heavily dependent on the operating environment the bus is subject to, so a

[1] The CUTR report included data from six Florida transit agencies including HART, LYNX, JTA, PSTA, Palm Tran, and PSTA.

percentage increase or decrease is more appropriate than using raw fuel use numbers from other metropolitan areas.

Operating and Maintenance Costs

Baseline operating costs for Metro Transit were established using 2012 data from the National Transit Database (NTD). Additional system data including revenue hours, recovery hours, and deadhead hours per route were obtained from Metro staff. Because revenue miles and total miles were not available by route, all calculations were done in terms of cost per hour. The fuel and maintenance costs per hour for standard-size vehicles were calculated based on 2012 reported fuel consumption and fuel price per gallon, and maintenance costs reported to NTD.

Articulated buses cost more to operate and maintain than standard buses because of their higher fuel usage and increased maintenance associated with an extra set of brakes and tires, as well as a more complex drive-train and the articulation joint. The cost per hour for large vehicles was calculated assuming a 33% decrease in fuel efficiency and a 43% increase in maintenance costs per hour. These values were combined with a constant value per platform hour for all other operating and maintenance costs that were assumed not to vary by vehicle size (such as operator labor and administration) to determine total operating cost per hour for each vehicle size (Table 7). Small buses have a slightly lower operating cost than standard buses due to their lower fuel use, but since the operation and maintenance of the bus accounts for about 90% of the cost, the overall operating costs between small and standard buses are similar.

Table 7: Hourly Operating Cost by Vehicle Size

	30-Foot	40-Foot	60-Foot
Fuel	$7.06	$7.77	$11.55
Maintenance	$16.39	$16.39	$23.47
Other operating costs (includes personnel wages, benefits, administration, and other costs)	$73.79	$73.79	$73.79
Total Cost per Platform Hour	$97.25	$97.95	$108.82

Note: Costs are for an individual vehicle on a per-hour basis, not per-rider.

Vehicle Lifecycle Costs

The lifecycle cost of small, standard, and large vehicles was calculated using the 2012 average annual platform hours and annual miles per vehicle, assuming 208 vehicles. The calculations by bus size include the purchase price for a heavy duty diesel bus, in addition to the assumed hourly operating expenses calculated previously. The purchase price for each bus size is the median price for New Flyer vehicles in that size.[2] Cumulative costs assume a 3.0% annual inflation rate. The lifecycle costs for each vehicle size are shown in Table 8.

Operating costs estimates include fuel, maintenance, and operator wages and associated costs. The 12-year life cycle cost model includes the purchase price plus an average of 2,040 platform hours per year with a 3% inflation rate. New buses are typically in use all day and accumulate many service hours in their first few years with declining use as they age, and often continue to be

[2] Small = 30 foot, Standard = 40 Foot, Large = 60 Foot. Small vehicle tested at 12 years, but certified as 10 year.

used past year 12 in Supplemental School Day Service – this detail is not shown for simplicity. Because of the similar operating costs between small and standard buses, there is a small difference in life-cycle cost between the two – mostly related to the original purchase price. Large vehicles are significantly more expensive over the long run, but if a large bus can replace two standard buses, there will be significant savings.

Table 8: Life Cycle Cost by Vehicle Size

		30-foot bus		40-foot bus		60-foot bus	
Year	Platform Hours[2]	Operating Cost [1]	Annual Costs	Operating Cost [1]	Annual Costs	Operating Cost [1]	Annual Costs
Purchase			$295,000		$425,000		$665,000
Year 1	2,040	$97.25	$198,390	$97.95	$199,818	$108.82	$221,993
Year 2	2,040	$100.17	$204,342	$100.89	$205,813	$112.08	$228,653
Year 3	2,040	$103.17	$210,472	$103.92	$211,987	$115.45	$235,512
Year 4	2,040	$106.27	$216,786	$107.03	$218,347	$118.91	$242,578
Year 5	2,040	$109.46	$223,290	$110.24	$224,897	$122.48	$249,855
Year 6	2,040	$112.74	$229,988	$113.55	$231,644	$126.15	$257,350
Year 7	2,040	$116.12	$236,888	$116.96	$238,593	$129.94	$265,071
Year 8	2,040	$119.61	$243,995	$120.47	$245,751	$133.83	$273,023
Year 9	2,040	$123.19	$251,315	$124.08	$253,123	$137.85	$281,214
Year 10	2,040	$126.89	$258,854	$127.80	$260,717	$141.99	$289,650
Year 11	2,040	$130.70	$266,620	$131.64	$268,539	$146.24	$298,340
Year 12	2,040	$134.62	$274,618	$135.59	$276,595	$150.63	$307,290
Total Life Cycle Cost (millions)			$3.11		$3.26		$3.82

[1]Hourly operating cost increases 3% per year.

[2]Platform hours include Metro's total reported platform hours (2012 NTD) divided by the number of fixed-route buses in its Fleet.

Operating Scenarios

A series of scenarios were developed to illustrate how large or small buses could be deployed in the system and the resulting cost impacts. These scenarios are detailed in Table 9 and summarized below. It should be noted that the scenarios do not include costs for a new maintenance facility or bus stop changes to accommodate larger vehicles. However, they represent various options representing varying commitments to a diversified fleet.

The scenarios use a cost model that combines operating and capital costs into an annualized cost. The model also includes additional costs incurred from restructuring the system, including additional deadhead resulting from the restructures needed for fleet diversification. This model combines costs and does not take into account different funding sources – for instance, state funds are only used for Metro's operating costs and federal funds are primarily used for capital costs. However, both state and federal funding sources are currently being maximized, so any new costs – capital or operating – would likely need to find a new revenue source. All costs derived from the model are unadjusted 2012 costs in 2012 dollars. See Table 9 for more information on this cost model and the scenarios.

- **Scenario 1** – This scenario is the existing system. The total annual cost, including operating and capital, is $47.4 million.
- **Scenario 2** – Under this scenario, 10 standard buses would be replaced with small buses. Operating and capital costs would be slightly lower than existing, but overall costs would be approximately $36,000 a year higher due to increased deadhead and relief operating costs. The effect on passengers would be smaller buses on some routes and potential route changes.
- **Scenario 3** – Under this scenario, 13 standard buses on routes 2 and 80 would be replaced with large buses to reduce overcrowding. Costs would increase by approximately $648,000 a year compared to existing service.
- **Scenario 2+3** – Scenarios 2 and 3 may be combined with 23 standard buses replaced with 10 small buses and 13 large buses, with an increased annual cost of $684,000.
- **Scenario 4** – Under this scenario, 40 standard buses would be replaced with large buses on routes 2, 15, 28/56/57, 37/38, 44/48, 71, 72, 80, and 84. Annual costs would increase by approximately $1.8 million compared to existing service. This scenario does not include the full deployment of up to 48 large buses, assuming the large buses are deployed selectively on the most needed trips.
- **Scenario 5** – 40 standard buses would be replaced with large buses on routes 2, 15, 28/56/57, 37/38, 44/48, 71, 72, 80, and 84. To reduce costs, service would be reduced on routes 10, 15, and 38. Many service trips that were previously operated as extra buses have now been put into the official schedule as Route 10. By reducing service on Route 10, the previous extra bus trips would be eliminated. These targeted service reductions remove selected less utilized scheduled trips in order to capitalize on the new capacity. Annual costs would be approximately $910,000 higher than existing service.
- **Scenario 6** – This scenario was developed to determine the cost implications of supplementing existing trips on Route 2 with small buses that may also be used for off-peak service. This scenario is not recommended because operating two buses (a standard bus plus a small bus) is less efficient than operating one large bus. The total annual cost under this scenario would be approximately $711,000.
- **Scenario 7** – Under this scenario, extra capacity would be added to Route 2 by converting 5 standard buses to large buses. This scenario was developed to provide a comparison to Scenario 6. The estimated cost for Scenario 7 is $277,000, compared to $711,000 for Scenario 6, indicating that providing extra capacity by utilizing large buses is much more cost effective than supplementing standard buses with small buses.

The following are major findings from the scenario analysis:

- In every scenario, there is a cost increase compared to the existing system. Even when 10 standard buses are replaced with small buses, costs are estimated to increase due to additional deadhead and relief time.
- Introducing large buses will increase capacity, but it will come at a significant cost.
- Adding extra capacity by shadowing standard buses with “helper” buses is much more expensive than adding capacity by converting standard buses to large buses.

Table 9: Cost Model for Predicting the Cost Impact of Large / Small Buses under Different Scenarios

Scenario	Platform Hours	Op Cost per Hour	Operating Cost	Buses	Ann Cap per Bus	Capital Cost	Addl. DH / Relief	DH / Relief Op Cost	Addl DH Oper Costs	Total Annual Cost	Service Implications
1. Existing System	424,000	$97.95	$41,530,800	208	$28,400	$5,907,200	---	$97.95	$0	$47,438,000	Effective August 2013
2. Replace 10 standard buses with small buses	21,000	-$0.70	-$14,700	10	-$3,800	-$38,000	913 hr	$97.25	$88,741	$36,041	Some long routes may need to be restructured
3. Replace 13 standard buses with large buses	38,000	$10.87	$413,060	13	$16,000	$208,000	275 hr	$97.95	$26,953	$648,013	Routes 2 and 80 get large buses weekdays only
4. Replace 40 standard buses with large buses	84,000	$10.87	$913,080	40	$16,000	$640,000	2,540 hr	$97.95	$248,793	$1,801,873	Routes 2, 15, 28/56/57, 37/38, 44/48, 71, 72, 80, 84
5. 40 large buses, reduce service on Rts 10, 15, 38			$256,815			$441,200			$211,792	$909,807	See below
6. Small Bus Helper Concept - Route 2			$587,936			$123,000			$0	$710,936	Assumes small buses accumulate average use
7. Convert 5 buses to large for Route 2	18,165	10.87	$197,454	5	$16,000	$80,000	---		$0	$277,454	Assumes half normal annual use
Details for Service Reduction Scenario 5											
Reduce peak period Rt 10 to Sheboygan Ave	-3,000	$97.95	-$293,850	-2	$28,400	-$56,800	-127 hr	$97.95	-$12,440	-$363,090	Rt 10 am/pm to Sheboygan reduced to 20 min HW.
Reduce peak period Rt 15	-2,300	$97.95	-$225,285	-2	$28,400	-$56,800	-127 hr	$97.95	-$12,440	-$294,525	4 trips trips removed each weekday peak.
Reduce peak period Rt 38	-1,400	$97.95	-$137,130	-3	$28,400	-$85,200	-124 hr	$97.95	-$12,121	-$234,451	Grey shaded trips removed.
Details for Small Bus Helper Concept Scenario 6											
Total small bus helper concept - Route 2			$587,936			$123,000			$0	$710,936	Assumes small buses accumulate avg use
Add a small bus to each peak period Rt 2	6,096	$97.25	$592,836	5	$24,600	$123,000	---		$0	$715,836	5 new small buses for extra + off peak work
Convert 5 standard buses to small off peak	7,000	-$0.70	-$4,900	5	$0	$0	---		$0	-$4,900	Assume 2/3 annual use

Notes:

Platform Hours: "Replace 10 standard buses with small buses" and "Replace 40 standard buses with large buses" assume buses accumulate an average of 2,100 hours per year. Other scenarios show service hour estimates derived from Fall 2013 timetables.

Operating Cost per Hour: The number shown is the difference in hourly cost affected by the scenario. Figure assumes small, standard, and large buses have hourly operating costs of $97.25, $97.95, and $108.82, respectively.

Buses: The number of buses in the fleet affected by the scenario.

Annual Capital Cost per Bus: The annualized total capital cost difference per bus affected by the scenario. Figure assumes small, standard, and large buses have capital costs of $295, $425, and $665 thousand, respectively, with useful lives of 12, 15, and 15 years, respectively.

Additional Deadhead / Relief: Addiltional deadheading and relief costs caused by the scenario because different sized buses can no longer be interlined and drivers may need to travel to/from a transfer point to start/end their shift. For the removal of service, it also includes deadheading between the garage and terminals which is not accounted for in Platform Hours. Figure generally assumes an average of 15 minutes per day per bus.

Deadhead Operating Cost: Operating cost of vehicles affected by the additional deadhead (may be different than the vehicles described in the scenario).

Calculations assume large buses are used weekdays only, unless otherwise noted.

GREENHOUSE GAS EMISSIONS

Each operating scenario was also evaluated for the effects it would have on greenhouse gas emissions. As shown in Table 10, replacing standard buses with small buses would lead to slight reductions in emissions, while utilizing large buses would lead to increased emissions.

Table 10: Fuel Use and Greenhouse Gas Emissions by Scenario

Scenario	Fuel (gal)	Tons GHG	% Change
1. Existing System	1,236,780	13,879	
2. Replace 10 standard buses with small buses	-3,730	-42	-0.3%
3. Replace 13 standard buses with large buses	+37,646	+422	+3.0%
4. Replace 40 standard buses with large buses	+90,711	+1,018	+7.3%
5. 40 large buses, reduce service on Rts 10, 15, 38	+70,066	+786	+5.7%
6. Small Bus Helper Concept - Route 2	+13,962	+157	+1.1%
7. Convert 5 buses to large for Route 2	+17,485	+196	+1.4%

Note: Greenhouse gas emissions assumed to be 0.011 tons per gallon of fuel consumed. Based on: http://www.epa.gov/OTAQ/climate/documents/420f11041.pdf

CORRIDOR CAPACITY

A major reason to add large buses to the Metro fleet would be to add capacity. Table 11 below provides three examples of how capacity (seats + standing capacity) would be increased given the deployment of large buses on all routes suitable for large buses.

- The stop at University & Midvale is on the busy University Ave corridor, where buses are frequently overcrowded. Deploying large buses on routes 2, 15, 56, 57, 71, and 72 would increase overall capacity by 21% during the period from 7:30 a.m. to 8:30 a.m. Routes 10 and 11 would continue to operate on the corridor with standard buses.
- The stop at Broom & Doty is along one of the main corridors into Downtown and is served by routes 10, 19, and 38. Using large buses on Route 38 would increase overall capacity at the stop by 13% during the period from 7:30 a.m. to 8:30 a.m.
- The stop at Linden & Charter is on the University of Wisconsin Campus and is served all day by Route 80. Utilizing large buses on Route 80 would increase capacity by 36% during the period from 12:00 p.m. to 1:00 p.m.

Table 11: Capacity Increase from Adding Large Buses

Location	Time Period	Capacity per Hour - Current	Capacity per Hour with Large Buses[1]	Change
EB University at Midvale	7:30 a.m. – 8:30 a.m.	1,385	1,672	+21%
NB Broom at Doty	7:30 a.m. – 8:30 a.m.	666	755	+13%
WB Linden at Charter	12:00 p.m. – 1:00 p.m.	580	790	+36%

Note: 1. Based on deployment of 40 large buses on the following routes: 2, 15, 28, 37, 38, 44, 48, 56, 57, 71, 72, 74, 80, 84

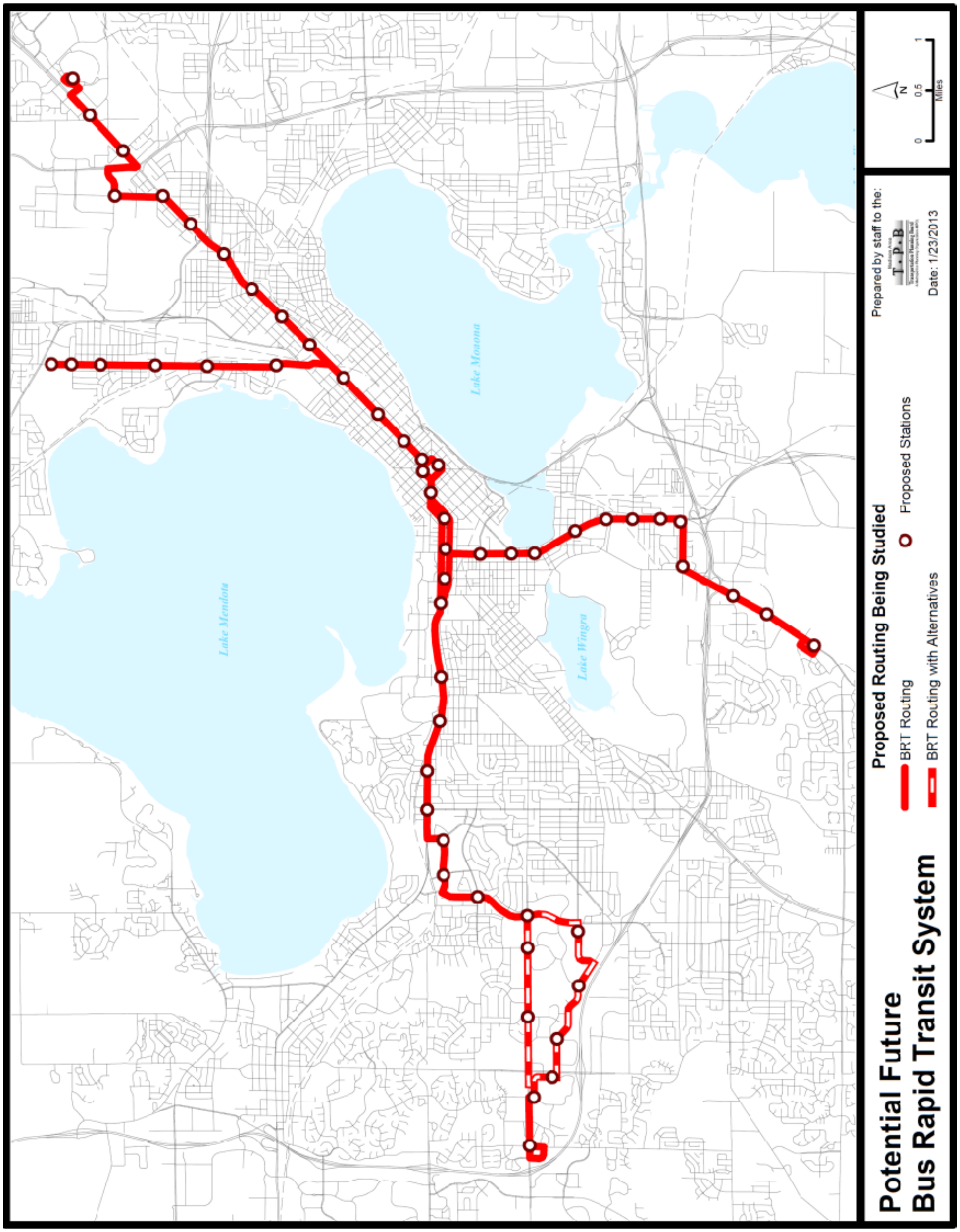
6 BUS RAPID TRANSIT

The Transit Corridor Bus Rapid Transit (BRT) Study completed by the Madison Area Transportation Planning Board and SRF Consulting in Spring 2013 assumed the use of articulated vehicles on two BRT lines (see Figure 26 on page 6-2). The east-west BRT line runs from the West Towne to East Towne areas via Mineral Point Road or Odana Road, University Avenue, and East Washington Avenue. The north-south BRT line runs from Fitchburg to north Madison via Fish Hatchery Road, Park Street, East Washington Avenue, and Sherman Avenue, effectively terminating as Route 22 and/or at the Dane County Regional Airport. The two lines share a common routing through the UW campus and downtown Madison via University Avenue / Johnson Street, State Street, the Capitol Square, and East Washington Avenue, with several alternatives in that area. Conceptual routing and stations for the BRT system is shown in Figure 26.

The findings of the Bus Size Study generally support the assumptions in the Transit Corridor Study. Large buses are recommended primarily in the west corridor (Routes 2, 15, 56, and 57) but also in the north corridor (Routes 2 and 28) and the south corridor (Route 44/48). Although Route 6, serving the east corridor, was not identified as needing a large bus, it consistently produces strong ridership throughout the day and it is suspected that its loads may actually peak during the mid-day, at certain class change times, or at other times and in locations not surveyed. Further analysis is needed to assess capacity needs and ridership towards the periphery of these BRT lines where ridership may be low, and conversely in the center city where capacity may be needed to accommodate BRT ridership.

Routes 38, 71, and 72 are the only routes identified as a large bus candidate that are not represented directly by one of the BRT corridors, though they were evaluated in whole or in part through the BRT study. Parts of the Route 38 service area (Broom/Basset Street, Jenifer Street, and east Madison) were investigated during planning for the BRT study but were dismissed for further study for several reasons. First, Broom/Bassett Street and Jenifer Street are low speed and circuitous and did not meet the goals established for the BRT system of reducing travel time. Second, the land uses east of Fair Oaks Avenue are relatively low density and residential in character with few defined commercial corridors that would be suitable for BRT service. Middleton service (Routes 70, 71, and 72) was also evaluated as a potential service corridor; however, because ridership is peak-oriented and major ridership generators are dispersed, it was recommended for potential consideration in future BRT phases. Routes 38, 71, and 72 comprise 14 (17 with spares) of the estimated 40 (48 with spares) large buses.

Figure 26: Potential Future Bus Rapid Transit System



Source: Madison Area Transportation Planning Board

7 OPERATIONS AND MAINTENANCE FACILITY EVALUATION SUMMARY

SUMMARY

An evaluation of the Metro Transit Operations and Maintenance Facility was conducted to determine if it could accommodate 60-foot articulated buses.

At the present time, the facility does not have any extra capacity to accommodate articulated buses if 40-foot buses are replaced on a one-to-one basis with articulated buses due to a lack of storage space. Replacing some 40-foot buses with 30-foot buses would open up a small quantity of space in the facility, but even at the maximum envisioned small bus deployment (13 buses), doing so would not alleviate storage issues at the facility.

It appears unlikely that the storage space obstacles can be overcome, indicating that articulated buses cannot be deployed in the fleet without a new or expanded facility. However, if the space constraints were overcome, the facility could accommodate articulated buses with some limitations:

- There are no obstacles for exterior travel. Articulated buses can both enter and exit the facility.
- The fare collection, vacuum, and washing stations are accessible to articulated buses.
- The facility has a pull-through maintenance area that could potentially service articulated buses, although this would require some re-organization of the present layout of the maintenance area and may reduce some of the efficiency gained with the current grouping.
- Articulated buses will not fit in the room dedicated to painting the exterior of vehicles, so alternative arrangements to paint articulated buses would need to be made.
- Articulated buses could circulate freely throughout the facility, and parking areas could accommodate the vehicles, if capacity existed to do so.

To be able to accommodate articulated buses, a new operations and maintenance facility must be constructed. Storing the maximum envisioned number of articulated buses (48 including spares) would require about 45,000 square feet of space(just over an acre) but this figure does not include space for servicing or maintenance activities.

METHODS

The purpose of this section is the assessment of various physical aspects related to the deployment of a mixed fleet as it relates to the Metro Transit maintenance facility. Particular attention was given to how larger articulated buses might be maintained, maneuvered, and stored within the facility. The articulated bus from the AASHTO 2011 library of vehicles was used for modeling movements. An on-site evaluation and tour was conducted on October 29, 2013 with

Jeffrey Butler, Transit Maintenance Manager. Scaled aerial images were used as a base map in addition to field measurements. All figures, including building diagrams and photos, can be found at the end of this section.

EXTERIOR TRAVEL

Articulated buses can both enter and exit the maintenance building. The most typical vehicular movements made outside of the facility are shown in figures 28 and 29. Buses typically enter the facility at doors 1, 2 and 3 from S. Ingersoll St. Figure 28 shows turning movements from southbound and northbound S. Ingersoll St. Buses most frequently exit door 4 as shown in Figure and enter S. Ingersoll St. There do not appear to be any obstacles or obstructions preventing these movements.

INTERIOR TRAVEL

The interior of the maintenance building is divided into several general areas which include Maintenance Areas A and B, Service Lanes 1 and 2, and Storage Areas A and B. Figure 30 shows the most typical vehicular movements inside the facility. There are four main doors for allowing vehicles to enter and exit the facility. Doors 1-3 are generally for entrance and door 4 is an exit. Entering at Door 1 is the route a bus might take to go directly to the maintenance area. Buses travel the facility in a one-way clockwise direction. The map used to show movements inside the building are approximate based on some field measurements and a schematic of the facility layout.

Service (Daily – Clean, Fuel, Fares)

Buses typically enter the facility through Door 2 and go through Service Lanes 1 or 2 as shown in Figure 30. The service lanes handle fare collection, interior cleaning of the buses with a vacuum system, fueling, and the last step is an exterior wash. These services occur in an assembly line like fashion and would work with the articulated buses. Articulated buses may be restricted to using service lane 1 so that they can more easily exit this area and proceed to the storage area.

Maintenance

Maintenance Area A is the area where the majority of the maintenance of the vehicles occurs. There are approximately 12 adjacent bays that form a saw tooth pattern when occupied. Different servicing activities generally occur in specific bays. For example, a pair of bays may be reserved for transmission work while others are used for brake repair. The buses generally back up into the bays for servicing. Articulated buses cannot use these facilities since the bays are not long enough, they do not have the right sized vehicle lifts and it would be difficult for articulated buses to back up into these areas. There is also a room dedicated to painting buses that is accessed from the exterior that can only accommodate 40-feet long buses (see Figure 41).

Maintenance area B is an enclosed room and is the most likely location for servicing articulated buses. It is accessible to an articulated bus but requires that the bus leave the service lanes and completely circle around Storage Area A to access from the west side. It currently has one vehicle lift capable of lifting an articulated bus. It has the potential to accommodate up to 4 articulated buses at a time.

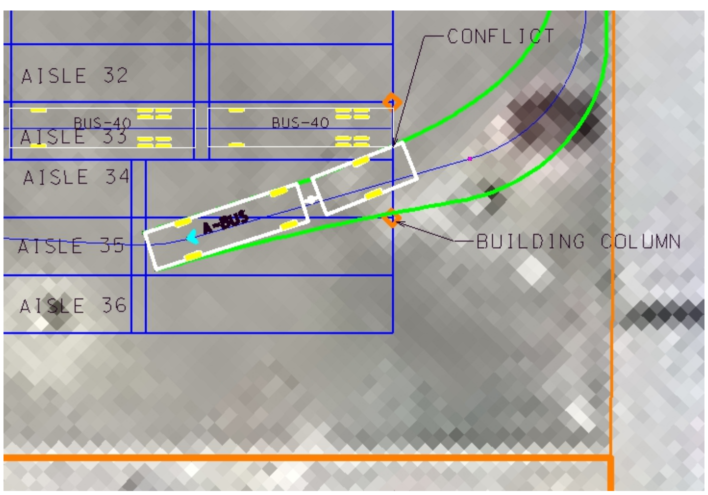
Storage

At the present time, the facility does not have any extra capacity to accommodate articulated buses if 40-foot buses are replaced on a one-to-one basis with articulated buses due to a lack of storage space. It appears unlikely that this obstacle can be overcome, indicating that articulated buses cannot be deployed in the fleet without a new or expanded facility. However, if the space constraints were overcome, such as storing part of the fleet elsewhere, articulated buses could be accommodated in the facility in terms of servicing and regular maintenance.

The facility has two main Storage Areas A and B (see Figure 31). The B area represents aisles 1-20. Vehicles that do not depart as frequently (school trips) and/or are nearing the end of their useful life are more likely to be stored in this area. The Hybrid-Electric buses are not allowed in this area because of lower vertical clearances, see figures 42 and 43. It is unlikely that the articulated buses would be stored in storage Area B, due to overhead clearance and side clearance issues. The passage ways are not as wide and turning movements are more difficult to accomplish. Specifically, the corridor used prior to turning 90 degrees into the aisle is narrower in Area B than in Area A. Note that the Hybrid buses, newest in the Metro fleet are also restricted to storage Area A. This restriction further complicates the storage puzzle.

Storage Area A consists of Aisles 25-36 (see Figure 31). It is important to note that the area is generally filled starting with the northern Aisle 25 and proceeding south toward Aisle 36. Filling the storage areas in this order allows vehicles to encroach into the adjacent aisle while maneuvering to park which is required to maneuver past the structural columns at the head of set of two rows. Articulated buses will also need to encroach into adjacent areas while parking, and the easiest aisle for the larger vehicles to park will be the last two aisles, numbers 35 and 36. If a third row of articulated buses is necessary, it will be easier to fit them in Aisle 33 instead of Aisle 34 due to the presence of a building column between aisles 34 and 35 that would limit the ability of the articulated bus to encroach into the adjacent aisle if buses are present in Aisle 33. See the conflict in the illustration below.

Figure 27: Storage Conflict



Aisles 33, 35 and 36 could accommodate twelve articulated buses (four in each aisle) without encroaching on a fire lane in the middle of the storage area. The aisles could also accommodate an additional 40 foot bus, but that would significantly complicate the bus parking progression.

Alternatively, Figure 30 also shows that four articulated buses could also be stored in both aisles 27 and 29. These shorter aisles would make the most efficient use of the space. These aisles typically store six regular sized buses. Aisles 28 and 30 could potentially have a conflict with the building columns as shown in Figure 29.

It is very important to note, even under the most efficient storage condition using aisles 27, 28, and 29 (while aisle 28 may not be ideal due to the column conflicts, it is possible to maneuver an articulated bus into the same space as a standard length bus), this scheme could store 12 articulated buses. But they would displace 18 standard buses in those lanes, plus an additional six standard buses due to the interference with maneuvering past the columns by encroaching in an adjacent lane, essentially leaving a "buffer aisle" between the two groups of buses. For example, if articulated buses are parked in aisles 27, 28, and 29, standard buses could not get into aisle 26 if there are already articulated buses in aisle 27, because they will not be able to encroach. This need for a buffer aisle reduces the capacity of the storage area further. Therefore, on a one to one replacement, additional storage for up to twelve standard buses would have to be obtained, somewhere.

SUMMARY

At the present time, the facility does not have any extra capacity to accommodate articulated buses if they replaced 40-foot buses on a one-to-one basis due to a lack of storage space. It appears unlikely that this obstacle can be overcome, indicating that articulated buses cannot be deployed in the fleet without a new or expanded facility. However, if the space constraints were overcome, such as storing a portion of the fleet elsewhere, the facility could accommodate articulated buses with the based on the following summary:

- There are no obstacles for exterior travel. Articulated buses could both enter and exit the facility.
- Articulated buses could circulate freely throughout the facility, and parking areas could accommodate the vehicles, if capacity existed to do so.
- The fare collection, vacuum, and washing stations are accessible to articulated buses.
- The facility has a pull-through maintenance area that could potentially service articulated buses, although this would require some re-organization of the present layout of the maintenance area and may reduce some of the efficiency gained with the current grouping. This area could maintain up to four articulated buses at one time. This implies a maximum fleet that could be maintained in this location of not more than 20 articulated buses if the storage issues could be overcome.
- Articulated buses will not fit in the room dedicated to painting the exterior of vehicles, so alternative arrangements to paint articulated buses would need to be made.
- The combined number of articulated and hybrid buses could not exceed the capacity of bus storage area A unless some other storage arrangements were possible.

Figure 28: Exterior Travel Patterns – Entering the Facility

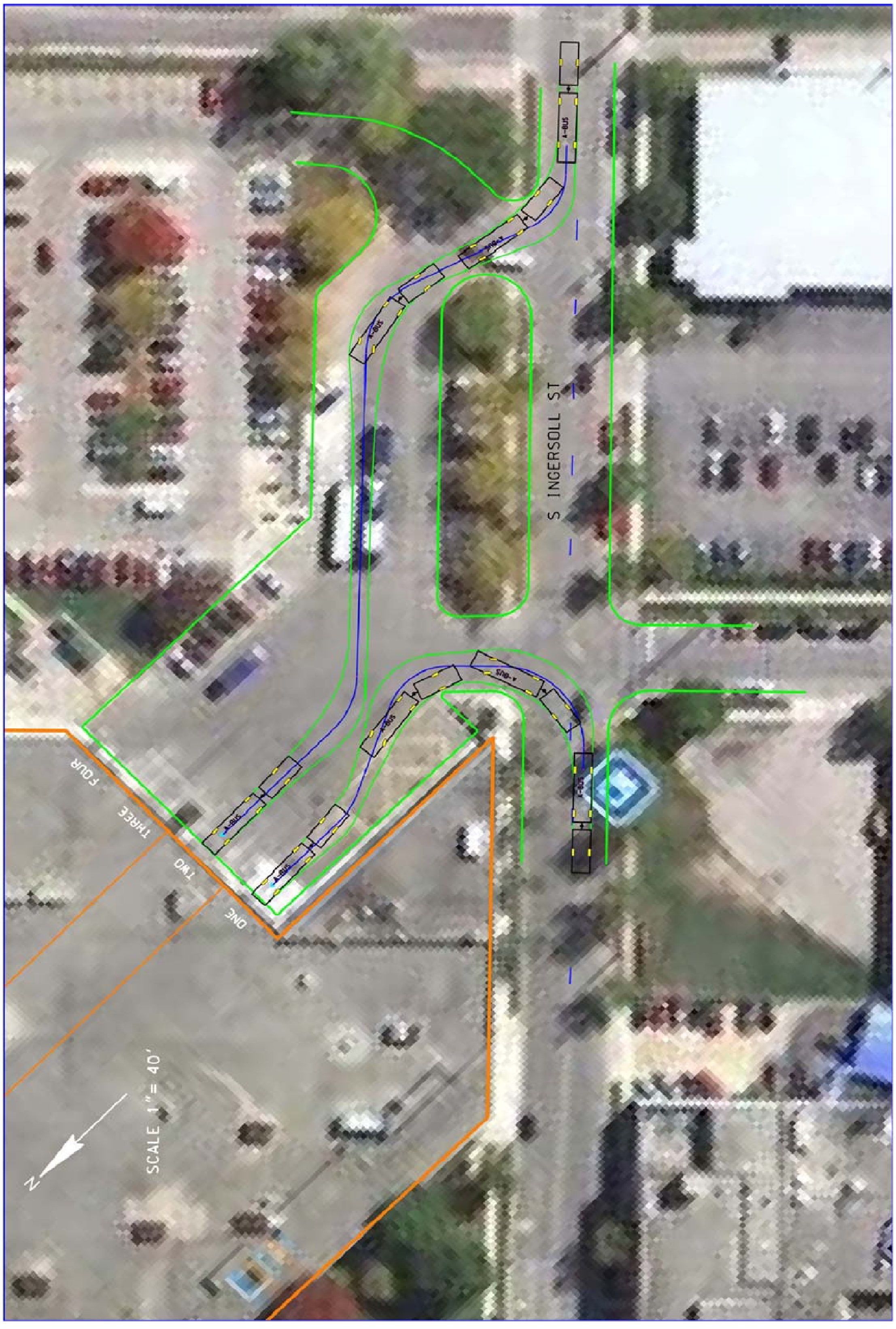


Figure 29: Exterior Travel Pattern – Exiting the Building; Interior Travel Pattern – Route to Storage Area A; Storage Options

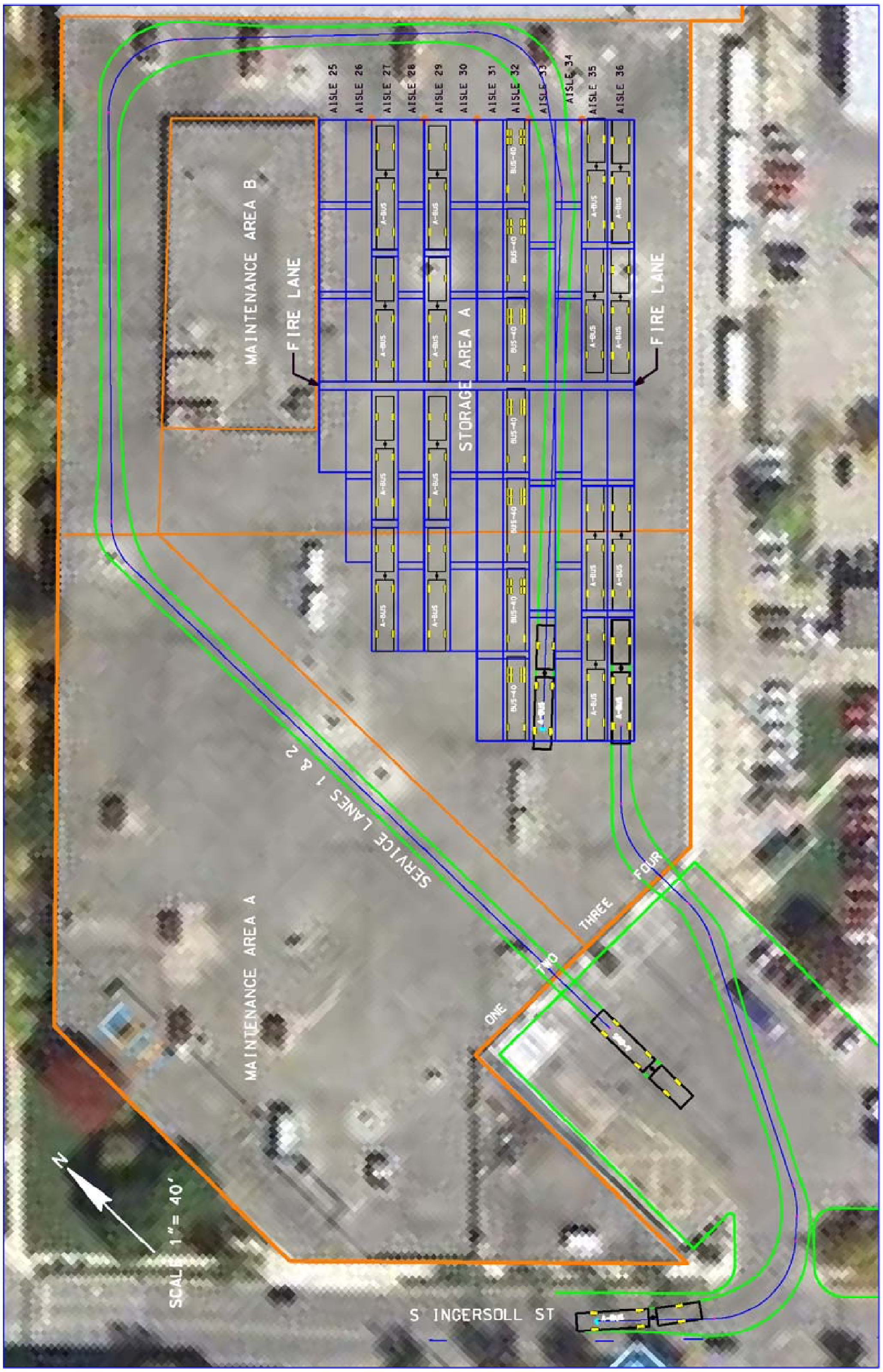


Figure 30: Interior Travel Pattern – Route to Service Lanes 1 & 2, Maintenance Area B; Storage Options.

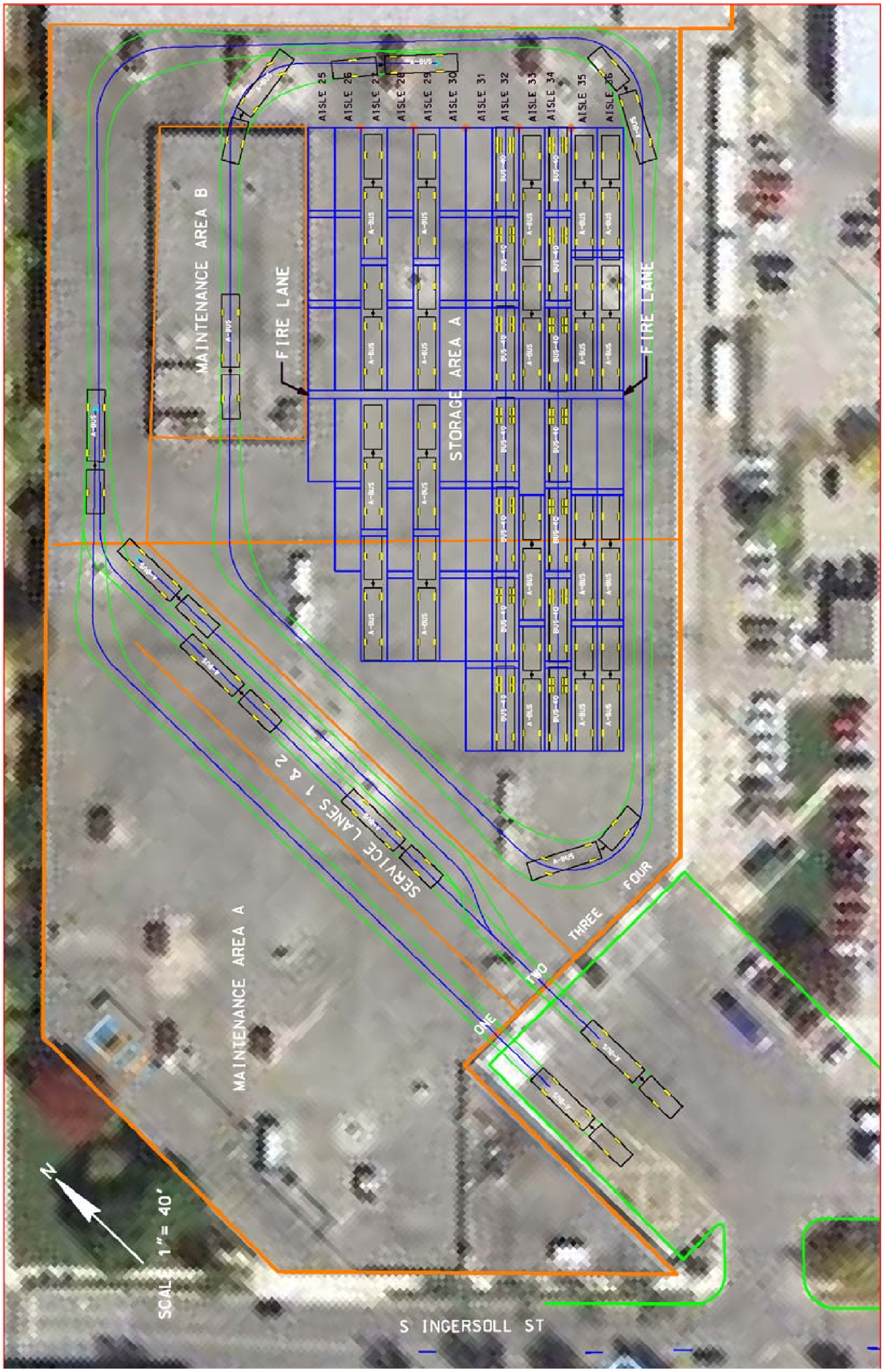


Figure 31: Building Schematic

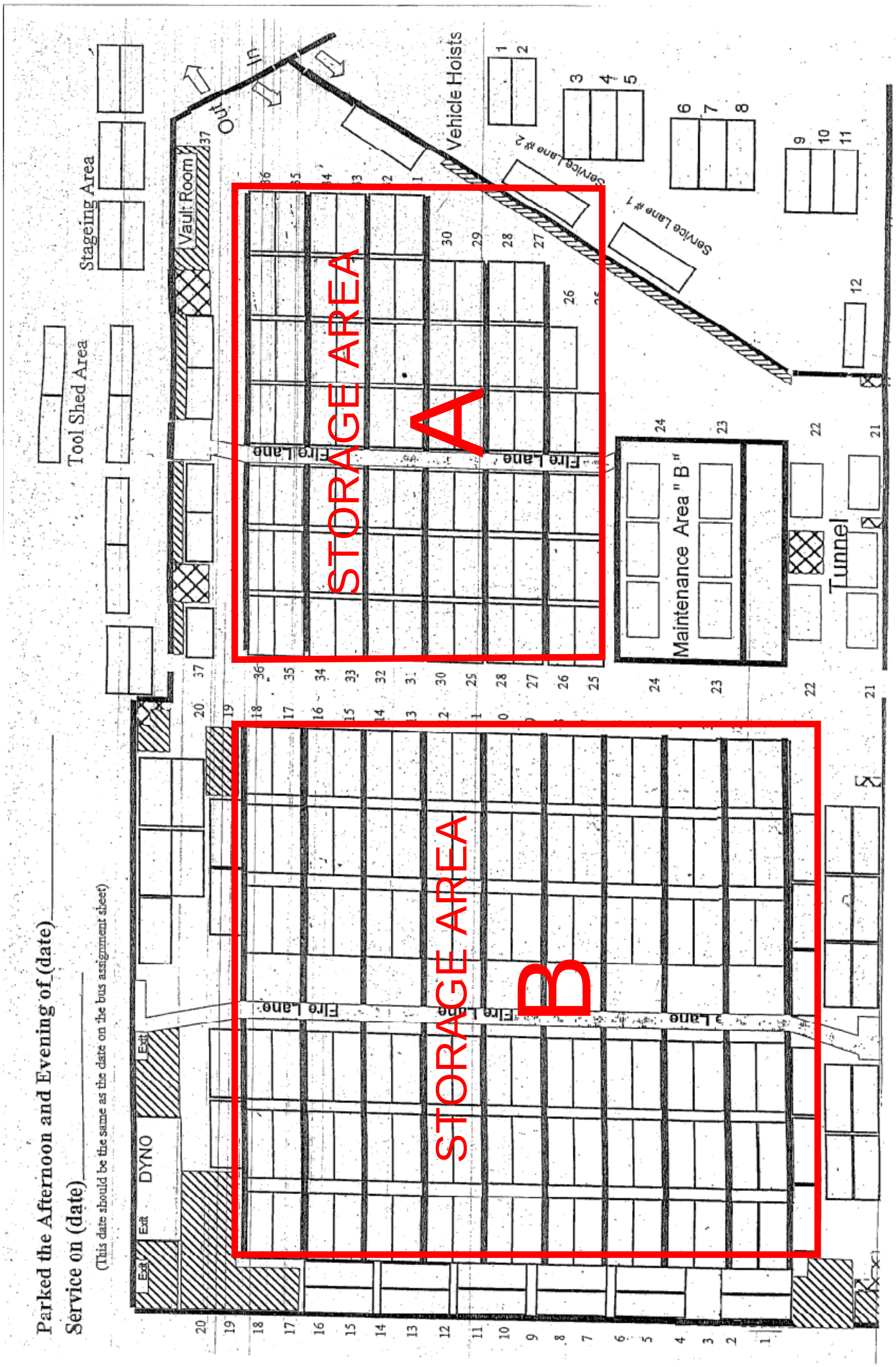


Figure 32: Entrance Doors 1, 2, and 3

Figure 33: Entrance Door 3, Exit Door 4

Figure 34: Service Lanes 1 and 2

Figure 35: Maintenance Area "A"

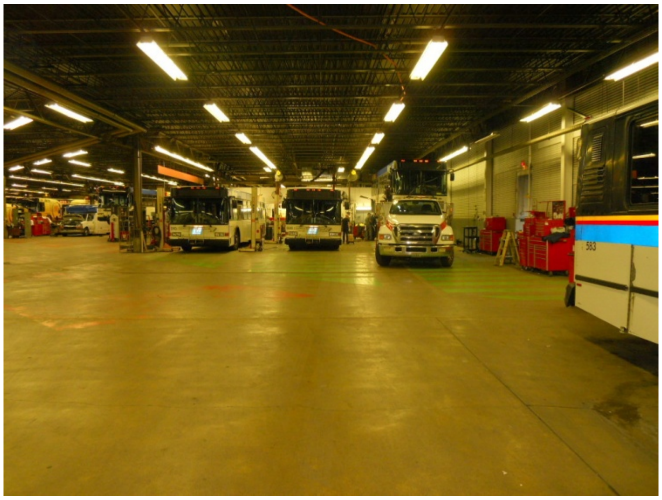


Figure 36: Maintenance Area "B" with 60' Vehicle Lift

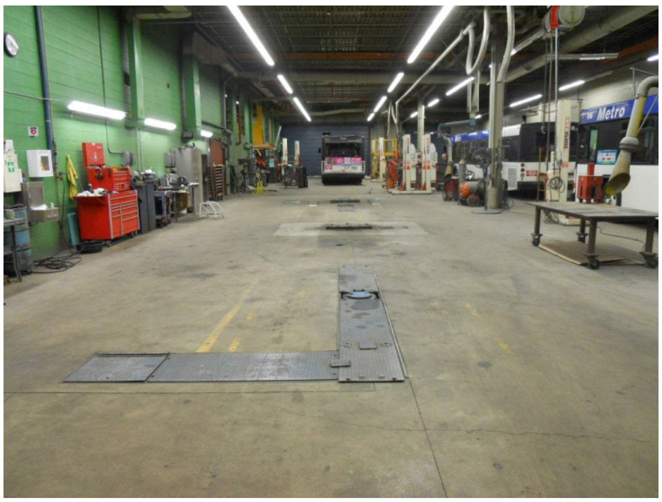


Figure 37: Storage Area "A" – Aisles 34, 35, and 36

Figure 38: The End of Storage Area "A"

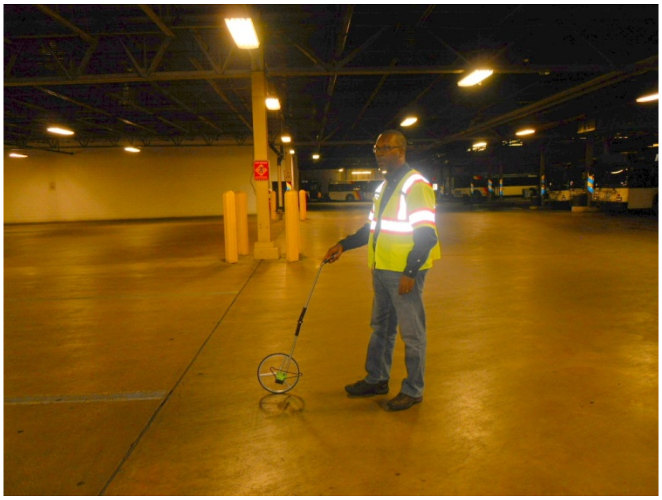


Figure 39: Fire Lane in Storage Area "A"

Figure 40: The Beginning of Storage Area "A"

Figure 41: Painting Room

Figure 42: Low Overhead Clearance in Storage Area B

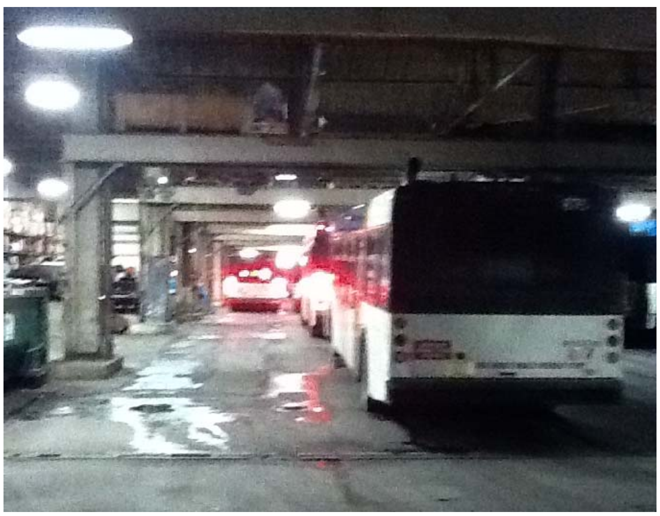


Figure 43: Higher Clearance Required for Hybrid Buses

8 BUS STOP AND ROADWAY EVALUATION

BUS STOP EVALUATION

This study included an evaluation of bus stops on routes being considered for large buses. This evaluation identifies bus stops that may need to be expanded in the future to accommodate large buses.

Methods

Bus stops serving the routes under consideration for articulated buses were examined using field review, satellite imagery, and anecdotal observations when possible to ascertain if a stop could accommodate an articulated bus.[3]

The following guidelines, furnished to the study team and gathered from field review and observations, were considered during this study:

- The typical length of the pull in space may be 40' or 60' before a near side stop, though numerous Metro bus stops may have less space.
- The posted *No Parking* area for bus stop zones has generally been no more than 110' for mid-block stops. The *No Parking* area for near side stops is typically 100' and 80' for far side stops, both of which usually reach to the intersection radius so that their effective length to prevent encroaching on stop bar and crosswalk markings would be less.
- Parking restrictions near bus stops are typically enforced with signage whereas a *No Parking* sign is included in the corner of the bus stop sign. It is not standard to have curbs painted to delineate *No Parking* areas at bus stops though bus stop areas occasionally feature painted curbs.
- Near side stops may be posted with a sign upstream of the boarding location in conjunction with a *Board Bus at Corner* sign. This arrangement allows for only one sign to do the job of two signs - one designating a bus stop and one for a *No Parking* area.
- The general preference for new or relocated bus stops is far side, with some exceptions. This alleviates a number of problems, such as traffic queues blocking access to bus stops, the need for excessive parking removal to allow buses to properly access the curb, the difficulty for bus operators to see or identify waiting riders who may be hidden from sight by parked cars or mistaken for pedestrians crossing the street, and reduces the likelihood of a pedestrian crossing the street in front of a bus.

[3] Two websites, Metro Transit Tracker (http://webwatch.cityofmadison.com/webwatch/map.aspx?mode=v) and the University of Wisconsin-Madison's Transportation services (http://www.map.wisc.edu/) served as the primary sources for satellite imagery provided by Microsoft and Leaflet, respectively.

- Bus stops may feature paved areas for boarding and alighting. Bus stops with boarding pads that are lengthened or relocated will need to be fitted with a new boarding pads or be relocated to paved areas. Driveways should not be used as boarding pads.
- A bus serving a bus stop should not infringe on a crosswalk or intersection.
- Professional judgment is largely used to determine the suitability of a location for a bus stop. Many factors, such as turning maneuvers, adjacent land uses, the locations of driveways, and the presence of street furniture and utilities in the terrace influence where bus stops are placed. Some bus stops in Madison are substandard. This methodology does not recommend actions to bring these bus stops up to standards, but recommends actions where needed when the introduction of large buses would cause new problems.

Bus stops currently serve one or more standard buses, each of which measures 40' in length while an articulated bus measures 60' in length. The difference in length between a standard and an articulated bus amounts to 20' and is the length which is used as the minimum amount of additional space that must be available for each stop to accommodate an articulated bus in place of a standard bus. Bus stops which serve multiple routes which were identified as candidates for articulated buses were assessed to determine if a minimum of 40' of additional space is available in order for two articulated buses to access the bus stop simultaneously.

The following conditions and adjacent uses were evaluated for each bus stop:

- pull outs (PO)
- intersections (INT)
- parking/parking spaces (P/#PS)
- driveways (DW)
- crosswalks (CW)

The current design and existing conditions of each bus stop was assessed using measurements of the amount of space at and around each bus stop and by considering adjacent uses as necessary to determine the amount of available space.

Results

Overall

The majority of the bus stops examined in this study (57.7%) can currently accommodate articulated buses. However, many bus stops would need to be modified by lengthening or moving bus stops with impacts to on-street parking as well as signage and boarding pads. The most frequently used means of accommodating individual or multiple articulated buses at existing bus stops is extending bus stops where needed.

On-street parking is most heavily used in central Madison, so losing parking spaces would have the greatest impact in that area. Approximately 50 – 80 non-paid parking spaces would need to be removed from the area bounded by Farley Ave to the west, Drake St to the south, and Baldwin St to the east, in order to expand bus zones to accommodate articulated buses on all of the large bus candidate routes.

Table 12: Required Bus Stop Changes – All Routes

None Needed	333	57.7%
Require Change(s)	244	42.3%
Move Stop	166	28.8%
Modify Pull Out	20	3.5%
Remove Parking	80	13.9%
Total Stops	577	100.0%

Campus & Downtown Service Area Summary

Approximately 10 – 20 paid parking spaces would need to be removed from the campus and downtown areas in order to expand bus stop zones to accommodate articulated buses on all of the large bus candidate routes. Several of the stops are located on Capitol Square. On University Avenue, the dedicated bus lane makes it relatively straightforward to accommodate larger buses, although some signs may need to be moved. Route 80 has several bus pullouts (about 25% of the stops on the route) that appear to be specifically designed to serve traditional 40' buses, and would not work well for a larger, articulated bus. Though much of the traffic in campus areas such as Observatory Drive is dominated by buses and bicycles, stops could require modifications if larger buses were used.

Route Summaries

Route 2

The majority of the assessed bus stops which serve Route 2 (53.5%) require no change in order to accommodate an articulated bus.

A total of 60 bus stops could require one or more modifications in order to accommodate an articulated bus. These modifications could include moving 39 bus stops, the removal of at least 1 parking space adjacent to each of 22 bus stops, and the modification of an existing pull out for 3 bus stops.

Table 13: Required Bus Stop Changes - Route 2

None Needed	69	53.5%
Require Change(s)	60	46.5%
Move Stop	39	30.2%
Modify Pull Out	3	2.3%
Remove Parking	22	17.1%
Total Stops	129	100.0%

Route 15

The majority of the assessed bus stops which serve Route 15 (70.1%) require no change in order to accommodate an articulated bus.

A total of 52 bus stops could require one or more modifications in order to accommodate an articulated bus. These modifications could include moving 47 bus stops, the removal of at least 1 parking space adjacent to 11 bus stops, and the modification of an existing pull out for 2 bus stops.

Table 14: Required Bus Stop Changes – Route 15

None Needed	122	70.1%
Require Change(s)	52	29.9%
Move Stop	47	27.0%
Modify Pull Out	2	1.1%
Remove Parking	11	6.3%
Total Stops	174	100.0%

Route 28

The majority of the assessed bus stops which serve Route 28 (48.6%) require no change in order to accommodate an articulated bus.

A total of 54 bus stops could require one or more modifications in order to accommodate an articulated bus. These modifications could include moving 30 bus stops, the modification of an existing pull out for 10 bus stops, and the removal of at least 1 parking space adjacent to 16 bus stops.

Table 15: Required Bus Stop Changes – Route 28

None Needed	51	48.6%
Require Change(s)	54	51.4%
Move Stop	30	28.6%
Modify Pull Out	10	9.5%
Remove Parking	16	15.2%
Total Stops	105	100.0%

Route 37

The majority of the assessed bus stops which serve Route 37 (60.5%) could require no change in order to accommodate an articulated bus.

A total of 45 bus stops could require one or more modifications in order to accommodate an articulated bus. These modifications could include moving 38 bus stops, the removal of at least 1 parking space adjacent to 13 bus stops, and the modification of an existing pull out for 2 bus stops.

Table 16: Required Bus Stop Changes – Route 37

None Needed	69	60.5%
Require Change(s)	45	39.5%
Move Stop	38	33.3%
Modify Pull Out	2	1.8%
Remove Parking	13	11.4%
Total Stops	114	100.0%

Route 38

The majority of the assessed bus stops which serve Route 38 (55.2%) require no change in order to accommodate an articulated bus.

A total of 81 bus stops could require one or more modifications in order to accommodate an articulated bus. These modifications could include moving 47 bus stops, the removal of at least 1 parking space adjacent to 28 bus stops, and the modification of an existing pull out for 10 bus stops.

Table 17: Required Bus Stop Changes – Route 38

None Needed	100	55.2%
Require Change(s)	81	44.8%
Move Stop	47	26.0%
Modify Pull Out	10	5.5%
Remove Parking	28	15.5%
Total Stops	181	100.0%

Route 44

A total of 20 bus stops which serve Route 44, amounting to 40% of the assessed bus stops, require no change in order to accommodate an articulated bus.

A total of 30 bus stops could require one or more modifications in order to accommodate an articulated bus. These modifications could include moving 17 bus stops, the modification of an existing pull out for 11 bus stops, and the removal of at least 1 parking space adjacent to 5 bus stops.

Table 18: Required Bus Stop Changes – Route 44

None Needed	20	40.0%
Require Change(s)	30	60.0%
Move Stop	17	35.4%
Modify Pull Out	11	22.9%
Remove Parking	5	10.4%
Total Stops	51	100.0%

Route 48

The majority of the assessed bus stops which serve Route 48 (60.9%) require no change in order to accommodate an articulated bus.

A total of 9 bus stops could require one or more modifications in order to accommodate an articulated bus. These modifications could include moving 7 bus stops, the modification of an existing pull out for 1 bus stop, and the removal of at least 1 parking space adjacent to 2 bus stops.

Table 19: Required Bus Stop Changes – Route 48

None Needed	14	60.9%
Require Change(s)	9	39.1%
Move Stop	7	30.4%
Modify Pull Out	1	4.3%
Remove Parking	2	8.7%
Total Stops	23	100.0%

Route 56

About half of the assessed bus stops which serve Route 56 (50.7%) require no change in order to accommodate an articulated bus.

A total of 37 bus stops could require one or more modifications in order to accommodate an articulated bus. These modifications could include moving 30 bus stops, the removal of at least 1 parking space adjacent to 11 bus stops, and the modification of an existing pull out for 2 bus stops.

Table 20: Required Bus Stop Changes – Route 56

None Needed	38	50.7%
Require Change(s)	37	49.3%
Move Stop	30	40.0%
Modify Pull Out	2	2.7%
Remove Parking	11	14.7%
Total Stops	75	100.0%

Route 71

The majority of the assessed bus stops which serve Route 71 (57.6%) require no change in order to accommodate an articulated bus.

A total of 36 bus stops could require one or more modifications in order to accommodate an articulated bus. These modifications could include moving 28 bus stops, the modification of an existing pull out for 3 bus stops, and the removal of at least 1 parking space adjacent to 8 bus stops.

Table 21: Required Bus Stop Changes – Route 72

None Needed	49	57.6%
Require Change(s)	36	42.4%
Move Stop	28	32.9%
Modify Pull Out	3	3.5%
Remove Parking	8	9.4%
Total Stops	85	100.0%

Route 72

The majority of the assessed bus stops which serve Route 72 (62.5%) could require no change in order to accommodate an articulated bus.

A total of 39 bus stops could require one or more modifications in order to accommodate an articulated bus. These modifications could include moving 34 bus stops, the modification of an existing pull out for 3 bus stops, and the removal of at least 1 parking space adjacent to 2 bus stops.

Table 22: Required Bus Stop Changes – Route 72

None Needed	65	62.5%
Require Change(s)	39	37.5%
Move Stop	34	32.7%
Modify Pull Out	3	2.9%
Remove Parking	2	1.9%
Total Stops	104	100.0%

Route 74

The majority of the assessed bus stops which serve Route 74 (57.7%) could require no change in order to accommodate an articulated bus.

A total of 22 bus stops could require one or more modifications in order to accommodate an articulated bus. These modifications could include moving 17 bus stops, the modification of an existing pull out for 2 bus stops, and the removal of at least 1 parking space adjacent to 3 bus stops.

Table 23: Required Bus Stop Changes – Route 74

None Needed	30	57.7%
Require Change(s)	22	42.3%
Move Stop	17	32.7%
Modify Pull Out	2	3.8%
Remove Parking	3	5.8%
Total Stops	52	100.0%

Route 80

The majority of the assessed bus stops which serve Route 80 (64.6%) could require no change in order to accommodate an articulated bus.

A total of 17 bus stops could require one or more modifications in order to accommodate an articulated bus. These modifications could include the modification of an existing pull out for 12 bus stops, moving 3 bus stops, and the removal of a total of five parking spaces (2 parking spaces adjacent to 1 bus stop and 3 adjacent to another).

Table 24: Required Bus Stop Changes – Route 80

None Needed	31	64.6%
Require Change(s)	17	35.4%
Move Stop	3	6.3%
Modify Pull Out	12	25.0%
Remove Parking	2	4.2%
Total Stops	48	100.0%

Route 84

The majority of the assessed bus stops which serve Route 84 (80.0%) could require no change in order to accommodate an articulated bus.

A total of 3 bus stops could require one or more modifications in order to accommodate an articulated bus. These modifications could include the modification of an existing pull out for 2 bus stops and moving 1 bus stop.

Table 25: Required Bus Stop Changes – Route 84

None Needed	12	80.0%
Require Change(s)	3	20.0%
Move Stop	1	6.7%
Modify Pull Out	2	13.3%
Total Stops	15	100.0%

Next Steps

The results of the detailed stop assessment should be reviewed with a cost-benefit analysis using an estimate for modifications. This estimate should detail the potential cost of any modification that a stop might be subject to in order to accommodate an articulated bus or buses, such as moving a bus stop sign or altering a pull out, and should distinguish any preferences for one type of modification or another for stops where more than one option is available.

TRANSFER POINT EVALUATION

Madison has four main transfer points where service is focused in outlying parts of the community:

- West Transfer Point
- East Transfer Point
- North Transfer Point
- South Transfer Point

Each of these facilities is designed to accommodate eight 40-foot buses at once with the exception of the South Transfer Point, which can accommodate six 40-foot buses. Schedules on certain routes are timed so that buses converge at a transfer point at the same time and riders can transfer between them. Maintaining these timed transfers makes it easier to transfer within the system and improves travel times.

The transfer points are designed with 50-foot bays evenly divided along two curb lines on either side of an island. The bays are arranged on a continuous straight curb and each bay can accommodate a 40-foot bus while allowing space for bicycle loading and for buses to pull out independently.

Each transfer point was examined to determine if the location provided sufficient space for articulated buses. Buses often change route numbers at transfer points as well, so a bus will serve a different route after departing than it served upon arriving.

Table 26: Transfer Point Service for Routes under Consideration for Articulated Buses

Route	North Transfer Point	East Transfer Point	South Transfer Point	Middleton Transfer Point	West Transfer Point
2	X				X
15		X			
28/56/57	X				X
44-48			X		
72				X	
71/74				X	
Total Served	4	1	2	2	4

Figure 44: Metro Transfer Point

If articulated buses are deployed in the system and the transfer points continue to operate on the same timed transfer system as today, there will be instances when there is not enough lineal curb space to hold four buses at the same time if one, or more, is a 60-foot articulated bus. There are several options to make accommodations for this, depending on the location and situation:

1. Operate as today, but one bus would overhang the platform, which may require passengers of the overhanging bus to only use the front door.
2. Modify schedules to reduce the number of number of buses serving a transfer point at a given time. This could make schedules less convenient for riders and reduce system efficiency, as the transfer points are often where routes are "interlined."
3. Lengthen platform by reconstructing transfer point.

Which solutions Metro chooses would depend on the level of deployment of articulated buses and how they are used. If capacity issues at the transfer points are rare, solution 1 would likely be the best option. However, if issues are common, Metro would likely need to implement a more complete solution such as number 2 and/or 3.

The North Transfer Point serves 4 routes which are being considered for articulated buses. The current layout of the North Transfer Point is designed to accommodate 8 standard buses. There is no additional space to accommodate articulated buses because they would infringe on the crosswalks. As a result, the North Transfer Point may limit the ability to introduce large buses on Routes 2, 28, 56, and 57. In the long term, a complete solution to this problem would be to expand the transfer point to the south or east. The Madison Transit Corridor (Bus Rapid Transit) Study introduced a concept of relocating the transfer point to the east, closer to Sherman Avenue, allowing for more direct bus rapid transit service from central Madison to north Madison via Sherman Avenue.

The East Transfer Point serves only 1 route being considered for articulated buses. There may be sufficient space to replace 1 standard bus with 1 articulated bus by extending the platform to the west.

The Middleton Transfer Point, which serves two routes under consideration for articulated buses, is not constrained by space.

The South Transfer Point serves two routes which are being considered for articulated buses. There may be sufficient space curbside to extend inbound bay to accommodate 1 articulated bus in place of 1 standard bus. However, there are times when 7 buses are scheduled to be at the South Transfer Point at the same time, exceeding the capacity of the facility today. In the long term, it will likely be necessary to expand the South Transfer Point.

The West Transfer Point, which serves 4 routes being considered for articulated buses, is currently designed to serve 8 standard buses at a time. Capacity could potentially be increased by extending the platform to the west, allowing for 1 articulated bus in each direction.

ROADWAY EVALUATION

There will be limited issues associated with operating articulated buses on streets in Madison. The most significant issue is operating articulated buses when road conditions are snowy or icy. These buses can fishtail or jackknife when conditions are slippery, particularly on hills. A snow plan will need to be developed to replace articulated buses with standard buses when there are slippery conditions and/or plan snow routes that avoid hills. The most significant concern would likely be Route 80, which is a prime candidate for articulated buses because of its high demand, but it travels on hills on the UW campus.

It is unlikely that articulated buses would have problems navigating Madison streets in good weather conditions, as articulated buses have as good or better turning radii as standard buses.

9 RECOMMENDATIONS AND NEXT STEPS

Small buses may be worth considering for a handful of routes in the Metro system. If a decision is reached to include small buses in the fleet, it is recommended there be at least ten buses as that is a desirable minimum number to efficiently manage in the facility and to maintain. A smaller number could be acquired and deployed, but the lack of efficiency would very likely outweigh any real or perceived benefits. If the current route system were extensively restructured, a more substantial fleet of small buses could be deployed while maintaining customer-friendly capacity on lower demand routes. The trade-off is that some riders would need to transfer, thereby losing their one-seat commute of today.

There are significant opportunities to introduce large buses, but they come at a cost. Route 80/84 and University Avenue corridor routes such as Route 2 are the highest priority because reports indicate that they serve the most crowded areas and have consistent all-day service with significant loads occurring throughout the day. It will be a policy decision to determine if, and to what extent, standard-sized buses are replaced with articulated buses given Metro's budgetary constraints and limitations of the maintenance garage's capacity. The current garage has no capacity to absorb any articulated buses.

There are significant issues in front of Metro that must be addressed before moving to diversify the bus fleet, including the following:

- Engage the public to assess opinions regarding the addition of small and large buses to the fleet.
- Seek policy direction from elected officials regarding the addition of small and large buses.
- Approve this final report of the Bus Size Study.
- Develop a financial plan that includes a diversified fleet and funding partner contracts.
- Develop a plan for funding and construction of an additional, or replacement, operations and maintenance facility that can be designed in such a way as to service large numbers of articulated buses. Integrate the findings from this study into that plan.

In addition, the following next steps must be taken:

- A decision on the future of BRT in Madison. Many of the potential routes for articulated buses are key corridors under consideration for development of BRT. This needs to be understood in terms of the potential impacts on how articulated buses are deployed.
- Determine how a diversified fleet fits into the long-term vision of transportation in Madison that will be established in the city's transportation master plan.
- Determine if restructuring would improve the system, and if so, how a diversified fleet would fit into that system.

- Examine the potential integration of paratransit and fixed route with a vehicle that could perform both functions. This analysis was outside the scope of this study, but will be examined in the future by MPO/Metro staff.
- Develop a plan for operating articulated buses in snowy conditions.

10 FREQUENTLY ASKED QUESTIONS

1. What types of buses do we currently have?

Metro Transit's fleet includes 208 standard transit buses. These buses are 40 feet long, have two doors, about 35 seats, and are wheelchair accessible. They use diesel fuel; 19 of them are hybrids. They last about 12 to 15 years and are typical for urban transit systems. In addition, Metro has 17 "cutaway" vans with about eight seats and space for four wheelchairs used for paratransit service – individualized point-to-point service for people with disabilities. The cutaway vans are light duty and last 5-7 years.

2. What other types of vehicles are available?

Besides the standard 40-foot transit bus used by Metro, typical vehicle sizes include 30-foot buses, which typically have one door, and 60-foot buses, which have two or three doors. 60-foot buses are often referred to as "articulated buses" or "artics" because they bend in the middle. Other vehicle sizes are available, such as 35-foot buses, double-deck buses, and others, but they are less common.

3. Why does Metro only use 40-foot buses?

As a bus circulates through Metro's system, its loads vary greatly throughout the day. For instance, it may travel out to the periphery of the system in the early morning empty or with very few passengers, then bring in a full load of commuters with people standing in the aisles, potentially even passing people up because there is no space on the bus. The solution to this problem has been a standard-size vehicle that that would be able to handle both extremes. In addition, Metro's system is very complex – a bus that is standing room only downtown may continue to the periphery as a different route where it serves much fewer people. This "interlining" of buses creates efficiencies for operation and results in fewer bus-to-bus transfers, but makes it difficult to operate different vehicle types over different routes. However, because of recent growth in transit ridership causing severe overcrowding and potential new concepts like bus rapid transit, Metro is investigating using a combination of differently sized vehicles.

4. What is the capacity of a bus?

The capacity of a bus varies greatly depending on its layout and how willing people are to efficiently use space. A standard 40-foot bus holds 35 to 40 seats and another 15 to 20 people can fit in the aisle. Buses with center-facing seats in the front have three fewer seats than buses with forward-facing seats in the front, but they have more floor space for standees and better circulation. 30-foot buses hold about 25 seats and 60-foot buses hold about 55 seats. The overall crush-load capacity of 30-foot, 40-foot, and 60-foot buses is estimated to be 35, 55, and 80 people respectively. If the bus is crowded, look to the back – you can increase the capacity of the bus by moving back if there is space in the aisle.

5. How does Metro currently deal with overcrowding?

When overloads occur on routes, Metro may send an extra bus to help. This bus says "EXTRA BUS" on its head sign and is not listed in the timetable but operates on a regular schedule. It usually comes a few minutes before the bus that is overloaded, sweeping up early arriving passengers so that the normal bus can stay on time and not turn people away. Extra buses are usually only used to cover the part of the route where they are needed. Extra buses can be fairly cost effective; however, Metro does not have enough vehicles to deploy enough extra buses to solve all overcrowding problems. In addition, extra buses can be expensive because they require two buses and two drivers, doubling the cost of service without improving service frequency.

6. How much fuel does a bus use?

A bus's fuel use varies depending on the age and model of the bus, whether or not it is a hybrid, and its operating environment. Standard 40-foot buses get about 4 to 5 miles per gallon. 30-foot buses are estimated to use about 10% less fuel, and 60-foot buses are estimated to use about 30% more fuel. Buses in heavy traffic that make frequent stops use more fuel. Although this sounds like poor performance, a standard bus with 30 people on board is achieving about 130 miles per gallon per person.

7. How often does Metro buy new buses?

Metro buses typically last 12 to 15 years. Buses are loosely cycled through a duty cycle where new buses are out all day on busy routes, mid-life buses may only be out during commute times, and older buses are mostly used for Supplemental School Day Service. Metro normally buys 10 to 15 new buses every year to replace older buses.

8. How much does a bus cost?

Standard 40-foot buses currently cost about $400,000, depending on the manufacturer and what options are included. By the time Metro is ready to enter into a new contract for buses, this cost is expected to rise to $450,000. Although Metro has not purchased any 30-foot or 60-foot buses in recent history, they are estimated to cost about $295,000 and $665,000 respectively. Upgrading a bus from standard diesel to hybrid diesel-electric power adds about 10%. Metro uses a combination of federal and local funds to purchase buses. Federal funding for new buses has substantially decreased and new sources of funds may be needed to continue this cycle.

9. How much does it cost to operate a bus?

The cost of operating a bus depends on what is counted. The cost of the driver, fuel, maintenance, supervision, general administration, and other direct costs is about $100 per hour. Since fuel costs are a relatively small part of the overall cost of service, the operating costs for 30-foot and 40-foot buses are nearly identical. 60-foot buses cost about $10 more per hour to operate because of increased maintenance costs associated with the articulation joint and extra set of tires and brakes.

10. What is the life cycle cost of the different bus sizes?

Combining the purchase price and long-term operating expenses of a bus, it costs an estimated $3.3 million to operate a standard 40-foot bus over the course of 12 years. A small 30-foot bus is estimated to cost $3.1 million, and a large 60-foot bus $3.8 million.

11. Is this related to bus rapid transit?

The two planning efforts are related. Bus rapid transit is a corridor bus line with frequent service, direct routing, limited stops, enhanced stations, transit signal priority, potentially dedicated bus-only lanes, and a tactile and reliable customer experience. The BRT planning study completed by the Madison Area Transportation Planning Board (MPO) in 2013 assumed that a future BRT system would use branded 60-foot buses. The current bus size study is looking at the transit system as a whole and asking – BRT or not – do large and/or small buses make sense. The routes identified in the bus size study for large buses generally operate in BRT corridors. The service restructure concepts needed to implement large buses and BRT service are similar.

12. Would using larger buses save money?

It is unlikely, large buses are more expensive to operate. Replacing a standard bus and extra during peak periods with one large bus reduces operating costs, but expenses add up as the large bus continues to operate throughout the day. In some cases, it is most cost-effective to target one extra bus to an isolated overcrowding problem than to replace the standard bus with a large bus.

13. How would small buses be used?

Small buses would typically be used on routes with lower ridership that are farther out. Potential weekday routes identified include Routes 13, 17, 31, 34, 39, and 52. Off-peak, the small buses may also transition to mid-day only routes like Routes 32 and 51.

14. Why can't we have a fleet of large buses that we use during the day and small buses for evenings and weekends when the system is less busy?

Metro has a spare ratio of about 16% – that is, of its 208 buses, only about 175 (84%) are actually in use during the busiest time. That way, buses that break down or need maintenance don't cause disruptions in service. Federal requirements dictate that spare ratios cannot exceed 20%. So if Metro were to purchase new vehicles but not add peak-period service, the spare ratio would go up, increasing capital costs with new buses we may need to purchase without federal funds. Metro strives to provide the most service it can within its budget and federal grants for new buses have been reduced. Therefore, <u>for Metro to include small buses in its fleet, it needs to find a place to deploy them during peak periods.</u>

15. Would a standard bus and small bus combined be better than a large bus – i.e., if you need to find a place for small buses during peak periods, can they do the work of extra buses (see #6)?

There are three reasons this is not practical. First, a standard and small bus costs more to buy and operate than a single large bus. Second, extra buses are deployed to busy areas at times when overcrowding occurs. Sometimes the extra bus gets as full as or fuller than the trip it is supplementing. Third, extra buses need to be versatile – their schedules change frequently and they are sometimes combined with Supplemental School Day Service, which can carry high volumes.

16. If you need to find a place for small buses during peak periods, can they do paratransit work?

Paratransit vans are purpose-built for transporting people, primarily people with disabilities, from point to point. As such, they do not have head signs or fare boxes and are light-duty – not designed for frequent stop-and-go operation. Heavy-duty transit buses, on the other hand, are not particularly well designed for paratransit work – just like standard-sized buses appear too big for lower-use peripheral service, a 30-foot bus would appear too big for paratransit. Because of this purpose-built design, mixing paratransit and fixed-route fleets is uncommon for medium- to large-sized transit systems. However, if we find that small buses cannot be mixed into the regular fixed-route fleet, investigating a hybrid vehicle that can transition between fixed-route and paratransit may be a worthwhile next step.

17. Why does interlining (See #5) play a role in bus size? Can't you easily change that?

Some interlines can easily be broken so that different vehicle types can be used on different routes. However, some interlines are necessary. Some routes travel into town as one route number and then back to their terminal as a different route number, so the interlined pair cannot be separated. Other routes need to be connected to each other to complete a valid loop. For instance, on weekends Route 32 takes 30 minutes to complete a loop on its own but has hourly service, so it is connected to Route 5 to have a cycle time that is divisible by its headway. This is the same example explained in #5 (Cycle Time) – for an explanation on these terms, see #5.

18. Where is Metro's bus storage and operations facility?

All Metro buses are stored and maintained at a facility at 1101 East Washington Avenue on Madison's isthmus. It is at capacity, limiting the ability to expand the fleet or replace standard 40-foot buses with new 60-foot buses. The bus storage and maintenance facility also does not have the ability to lift and maintain 60-foot articulated buses. Metro is looking for new temporary and permanent locations to expand its bus storage and maintenance capacities.

19. Will larger buses be able to stop in bus stops in Madison?

Most of the 2,000 or so bus stops in Madison are designed for standard 40-foot buses, so to accommodate larger 60-foot buses, some of them would need to be lengthened. In some cases, this would require no change at all. In other cases, it would require the removal of one or two parking spaces and minor signage changes. However, there are some locations where it may require that pull-out bays be lengthened, concrete boarding platforms be relocated, or the bus stop itself be moved or closed. For instance, the four major transfer points are specifically designed for six or eight standard 40-foot buses.

20. When would we start to see large or small buses in Madison?

Different sized buses, if they make sense, would likely be seen no earlier than about 2018 if no changes are made to the procurement cycle, and assuming storage space can be found for them. Metro normally plans bus purchases several years out.

11 GLOSSARY

Transit planners try to avoid jargon because it confuses people, but sometimes it is necessary because we need to communicate precisely with each other. Some basic definitions are listed below.

Trip – An individual line in the timetable. For example, Route 2 leaving the West Transfer Point at 7:00 am and arriving at the North Transfer Point at 7:52 am on weekdays is one trip.

Block – The daily duty of one bus. For example, a bus may leave the garage in the morning and cycle through many routes and drivers on its block, returning to the garage late at night. Assembling a block, which consists of several trips, is called blocking.

Run – The daily duty of one driver. For example, a driver may leave the garage driving a bus in the morning and be relieved by another driver doing a different run that afternoon. Assembling runs so that all blocks are covered is called run-cutting.

Deadheading – Driving a bus that is out of service. When a bus reaches its terminal and is done for the day, it deadheads back to the garage with "NOT IN SERVICE" showing on its head sign. The bus also may deadhead from the garage to its first terminal or between trips that do not share a common terminal. Metro minimizes deadheading to the extent possible, but with three times as many buses in service during the peak period compared to the mid-day, some deadheading is inevitable.

Articulated Bus – A bus that has a bending part in the middle that looks like an accordion (sometimes called an "artic"). Larger buses need to be articulated so that they can go around corners.

Interlining – When a bus reaches the end of its route and continues as a different route. Buses do not go back and forth on the same route all day; when they reach their terminal, they often continue as a different route. Connecting different routes together with the same bus is called interlining. It improves efficiency (buses do not have to deadhead as much), reduces the need for passengers to transfer, and is more equitable for bus operators.

Dodger or Tripper – A block that contains only one or two trips.

Frequency and Headway – Frequency is the number of buses that pass a point in a certain amount of time, usually an hour. Headway is the inverse of frequency, the length of time between buses. For instance, Route 2 usually has a frequency of two buses per hour and a headway of 30 minutes.

Cycle Time – The length of time for a bus to complete a loop and return to its starting point. A loop may consist of one or more routes interlined together that form a repetitive pattern. For instance, on weekends, Routes 5 and 32 are interlined together to form a loop with a cycle time of 120 minutes. This loop has two buses on it, resulting in a headway of 60 minutes or a frequency of one bus per hour.

Platform Hours and Revenue Hours – Hours of bus operation. Platform hours include deadhead, in service time, and recovery time (the few minutes at the end of the line before the bus begins its next trip). Revenue hours do not include deadhead time.

Supplemental School Day Service – Peak-period service open to the public designed to facilitate student commutes to middle schools and high schools without overcrowding main-line service. These routes have letters – W, E, M, and L – route maps and timetables are available at www.mymetrobus.com, click on "ROUTES & SCHEDULES", then "Supplemental School Service".

Transfer Point – Hub that facilitates passengers connecting to different bus routes. There are four major transfer points in Madison – South, North, West, and East – and a minor transfer point in Middleton. Bus schedules are written so that several bus routes come in and go out at the same time so that people do not have to wait as long to make connections.