Service Design Review

Scheduling Performance and Efficiency

Technical Memorandum

Introduction

Task 4 of the Transit Optimization Analysis (TOA) for the Southeast Valley Transit System Study (SEVTSS) included a review of current Valley Metro scheduling practices and their related outcomes. For this analysis, existing service effectiveness and operational efficiency were reviewed to provide a data-driven understanding of current performance and to build a foundation for developing recommendations.

The review primarily is focused on the application of the HASTUS scheduling software, and related tools, for the scheduling of the routes within the study area, which is confined to the Tempe and Mesa operating garages.

The kick-off for this task included familiarization with the HASTUS database organization and route structures within the study area. All key HASTUS scheduling related components, except runcutting and rostering, were examined.

The emphasis of this section of the study will determine if there are additional cost-savings or efficiency opportunities that can be achieved through improved scheduling practices or utilization of technology. TMD undertook evaluation of the scheduling processes at the district, garage, and route level.

Methodology

Communicating directly with Tempe staff, TMD discussed practices and procedures followed during the scheduling process. Remote access to the HASTEST database allowed TMD staff to analyze HASTUS Vehicle schedule tables, reports, and statistics in order to identify opportunities to improve the scheduling process and/or maximize resource utilization. Recovery times and in-service operating speeds were reviewed, deadhead and running time versions evaluated, and runtime data for three randomly selected routes was analyzed in HASTUS ATP. FY2014 On-Time Performance, blocking methodologies, blocking solutions, and garage assignment strategies were also examined.

Results and Recommendations

Overview

TMD was provided access to the Phoenix HASTEST database containing Tempe/Mesa schedule data within the "TMOT14" booking, which was subsequently used for this analysis. Scheduled, fixed route bus service, at the Tempe and Mesa garages is operated under contract by First Transit for 21 Local, 9 Express, 9 Community Circulator, and 2 LINK connector routes. All Local and selected Express routes operate standard 40-foot or articulated buses while Circulator, LINK and most Express routes are assigned specialized fleet types.

- Most local routes operate on weekdays every 30 minutes with several routes providing 15 minute service during the AM and PM peak periods. Half of the weekday routes operate from

approximately 5:00am until midnight with others terminating between 6:00pm and 10:00pm. On weekends, local routes may operate less frequently with reduced service spans. Express routes provide weekday peak hour tripper service only.

- Neighborhood Circulator routes operate weekdays from approximately 6:00am until 10:00pm with frequencies ranging from 10 minutes to 30 minutes. More than half of the Circulator routes operate on Saturdays and/or Sundays with modified hours and frequencies. One circulator operates in one direction only.

- The Arizona Avenue LINK line operates 7 days a week. Weekday service operates every 35 minutes between approximately 5:00am and 8:30pm. On weekends, hourly service is provided from approximately 6:30 until 11:00pm. The Main Street LINK line operates 15 minute peak frequency and an alternating 25/35 minute off peak frequency on weekdays from approximately 4:00am until 10:00pm.

Phoenix staff maintains the HASTUS variant and itinerary data and Tempe staff with feedback from Valley Metro operations staff defines scheduled running times. Phoenix provides headway information to Tempe schedulers who prepare initial vehicle schedules and blocking solutions. Proposed schedules are reviewed by Phoenix staff prior to approval of the final blocking solutions and garage assignments. Tempe staff may make additional blocking and/or scheduling adjustments to reduce vehicle requirements, balance garage assignments, or improve the blocking solution. For this process, Tempe staff builds and blocks the schedules in a non-production environment (HASTEST). These new solutions are then replicated in the production database (HASTUS). This would be a less time consuming and redundant task if Tempe staff were allowed to access the HASTUS environment to directly enter the schedule and block data [the usual process for multiple users or agencies], while still allowing for review and oversight by Valley Metro operations staff.

When the vehicle scheduling phase is complete, the contractor (First Transit) is responsible for the runcut and roster processes necessary for operational implementation. Currently, First Transit has the City of Phoenix staff undertake this effort for them.

Performance Measurements

Schedule Recovery Percent – A minimum 10% recovery is the target for Valley Metro routes assigned to the Tempe and Mesa garages. Recovery percent represents the ratio of extra time available in a round trip to help assure the next trip departs on-time. Since it protects service reliability, it is standard industry practice to include recovery time in total revenue hours. Recovery time beyond the minimum deemed necessary for reliability is considered inefficient and often lowers productivity. Excess recovery time may, however, be unavoidable under certain circumstances resulting from route design, headway, frequency, timed transfers, and other criteria that affect round trip cycle time efficiency.

Recovery times were analyzed for each schedule day type operated by First Transit from the Tempe and Mesa garages as shown in Table 1. The average recovery ratio for Community Circulator, LINK, and Local routes indicates more than adequate overall recovery has been provided for each service type (weekday, Saturday, and Sunday). It was noted that excess recovery over the 10% minimum exists for all service types other than express as highlighted in Table 1 below. In some of these cases re-blocking would reduce excess recovery and vehicle requirements while continuing to respect "Vehicle Type" restrictions. In all instances the service redesign recommendations should consider adjustments to the routes to minimize the inefficient round trip cycles that result in excess recovery time. Particular attention should be given to the LINK routes (all service days) and Local routes (especially on weekends). Attention to the impact of deviations on cycle time efficiency is also important to avoid the cost of an extra all-day bus with 1-2 operators when adding or continuing service deviations. Examples of excess recovery time where ¼ to ⅓ of the time is spent unproductively include:

Routes with excess recovery time (over 10%) should be reviewed and adjusted where feasible to minimize cycle time inefficiencies. Where not feasible, interlines should be considered.

- 120 – Mesa Dr (34%)
- 48 - 48th Street/Rio Salado (28%)
- Arizona Ave LINK (27%)

Express routes are not subject to the 10% recovery ratio target, since the service is tripper-based, rather than schedule-based. As a result, Express blocks normally operate only one or two one-way trips, generally only in the peak direction.

Recovery Percentages by Service Type			
Service Type	Weekday	Saturday	Sunday
Local	15.1%	18.7%	20.2%
LINK	27.9%	45.1%	44.3%
Circulator	13.2%	13.9%	15.5%
Express	1.9%	--	--

Table 1: Recovery Percentages by Service Type

Pull and Deadhead Time Percent – Pull and deadhead time percentage is the ratio of non-revenue hours to revenue hours and is shown in Table 2. "Pull Time", also referred to as "Garage Deadhead", is the time between the garage and route terminals. "Deadhead Time" is the time spent operating out of service from one terminal to another. Both Pull and Deadhead times are unproductive and should be minimized where possible.[1]

There are 395 deadhead trips scheduled in the TMOT14 booking with approximately 110 traveling to different terminal locations. For longer deadhead trips, using HASTUS Minbus [vehicle blocking optimizer] will likely find more suitable links to reduce unproductive time.

[1] Under the current operating contracts, the cost is based only on revenue miles at a set rate per mile. However, this rate per mile proposed by the contractor is based on the total revenue and non-revenue cost of the service operation divided by the planned revenue miles. Consequently, higher deadhead and pull time and miles manifest as a higher unit cost per revenue mile.

Many interline and non-interline deadheads have identical "Start" and "End" locations but require non-revenue travel between ending and starting points. Although these points are likely directly across the street, in some cases deadhead distances are in excess of 1.5 miles. This is an indication that simple turn-around opportunities are limited. The service design process should consider this, as well as a review of blocking strategies in order to reduce vehicle requirements. The result could be fewer pull trips and unnecessary vehicle assignments (single trip express buses, trippers etc.), as well as reduced high differentials in peak and off-peak bus requirements [peak-to-base ratio].

The Express routes have a very high percentage of non-revenue hours resulting from single trip blocks combined with more pull trips and longer pull durations, which are not unusual for express service and are reflected in the higher per trip costs associated with express operations. All other services have low pull and deadhead percentages, which is expected for services operating with low peak-to-base ratios.

Pull and Deadhead Time Percentages by Service Type			
Service Type	Weekday	Saturday	Sunday
Local	7.5%	6.0%	6.7%
LINK	7.4%	6.7%	7.7%
Circulator	4.0%	3.8%	4.6%
Express	43.1%	--	--

Table 2: Pull and Deadhead Time Percentages by Service Type

Operating Speeds – Operating speed reflects how fast trips are scheduled between timepoint segments. Scheduled operating speeds are based on segment conditions including traffic, signals, road speeds, number of stops, and expected ridership. Speeds that are excessively low or high are often reflected in poor on-time performance. This can cascade throughout entire the schedule and is a major cause of "Bus Bunching". Operators respond to excessive and insufficient running time inconsistently and this often results in additional, unnecessary resources and a poor experience for customers (reliability is the key factor for customer retention). Operating speeds as shown in Table 3 are within expected ranges for each service type.

Average Operating Speed by Service Type (mph)			
Service Type	Weekday	Saturday	Sunday
Local	15.4	15.8	16.1
LINK	18.8	22.9	22.7
Circulator	10.1	10.6	10.5
Express	25.5	--	--

Table 3: Average Operating Speed by Service Type

Scheduled operating speeds for Tempe/Mesa based Valley Metro routes vary depending on route characteristics. The average scheduled speed for free neighborhood "Circulator" routes is lower and those for "Express" routes, serving non-stop and freeway segments, are scheduled much faster. The LINK routes, which only stop at major intersections, are scheduled at an average speed of 18.8 mph with local routes somewhat slower at 15.4 mph. Based on the FY2014 on-time performance data, these scheduled speeds may be a bit slow for current travel conditions given high incident of early running (Table 4).

On-time Performance – As noted earlier, service reliability is the top issue for customer retention, which makes on-time performance a key transit metric. Using the typical On-Time Performance (OTP) standard of "no more than 1 minute early or five minutes late", overall FY2014 OTP for Tempe/Mesa based routes is just 61%. Early or "hot" running (> 1 minute early) represent 32% and with late running (> 5 minutes late) just 7% of recorded observations. This is unusual to have early running so prevalent given operating and scheduling best practice recognizing that running hot has a much more significant impact on the customer.

Adjust OTP "on-time" range to "up to one minute early to five minutes late" with both early and late running outside of the acceptable range.

Overall On-Time Performance for All Routes		
On-Time Status	Number of Observations Recorded	Percent of Total Observations
Early (>0h01)	1,413,920	31.57%
Late (>0h05)	330,501	7.38%
On-Time	2,734,329	61.05%
OTP Reported to RPTA		**92.62%**

Table 4: Overall On-Time Performance

On-Time measurements are not available for individual service types (Weekday, Saturday, & Sunday). The OTP measurements reflect the combined annualized on-time percentage. First Transit requires an on time operation of at least 90%, to meet the minimum performance standard. To achieve this, the On-Time Percentage is determined by adding the Early and On-Time measurements which result in On-Time Performance of 92.6%. *Again, early running is a major observed issue and the OTP target does not follow industry best practice which includes a range of up to one minute early to five minutes late as "on-time" and "early running" (greater than one minute ahead of schedule) as not on-time.*

Runtime Calibration – Runtime calibration is the process of refining in-service times between timepoints and timepoint segments. While runtimes are normally defined by route, which is the practice at Phoenix, it is not uncommon for system running times to be established and shared between routes operating along common corridors. As travel conditions change, it is also common for running times to vary throughout the day. These variances are implemented within HASTUS as "Runtime Periods." Runtimes affect operating speeds and schedule performance. Runtime periods, and the running times themselves, should be reflective of operating conditions, and be based on organizational and industry best practices.

In order for a complete and effective runtime analysis to occur, sufficient and accurate observed trip data needs to be available. The AVL system, installed on the majority of the Tempe/Mesa fleet, provides such data, which, when cleansed of erroneous or outlier records, is ideal for feeding into a running time analysis tool such as HASTUS ATP.

Tempe schedulers initially develop running times using preset operating speeds. For local routes, 12 mph in urban areas, 15 mph for suburban areas and up to 20 mph in suburban areas with low ridership. Higher operating speeds are used for Express type routes. Proposed route segments are then driven to

validate times. Driver and/or passenger complaints as well as low on-time performance cause routes to be reviewed.

As part of this study, TMD performed test ATP analyses on three local routes, using available AVL data (pre-loaded into HASTUS ATP). However, as a result of missing specific point data, it was not possible collect end to end or segment running times to verify on-time data. Furthermore, "ORBI" buses assigned to "Circulator" routes are not AVL equipped.

Although Tempe staff recently began using HASTUS ATP to assist in reviewing running times, it was found that the AVL data used was sometimes incomplete and contained erroneous records. It is therefore recommended that a review of the AVL data collection and cleansing process be performed. Additionally, the method used to load this data into the HASTUS environment should be assessed, as many instances of questionable measurements were observed. Valley Metro's AVL vendor (ACS), and or specialists should be able to assist with this. Procedures for on-going review of route running times, using ATP, should also be developed and implemented. Following this, HASTUS ATP should be used to perform a comprehensive analysis and calibration of running times for Mesa/Tempe based routes.

Runtime periods should also be reviewed and redefined. Runtimes for many routes do not adequately reflect changing driving conditions throughout the day. Several routes operate the same running time during peak and off-peak periods and several others carry the same running times over the course of the entire day. Valid AVL measurements, combined with a comprehensive ATP runtime analysis, will assist in identifying appropriate running times and runtime periods. *The unacceptably high levels of early running and the potential impact on resource requirements make runtime calibration a priority.*

Recommended next steps are a) identify a representative period of days to use for runtime analysis; b) clean the AVL data removing outliers and erroneous records; c) import into HASTUS ATP; d) review data in ATP and update running time periods (can vary by route); e) recalibrate running and recovery times following an industry best practice approach[2]; f) develop new service schedules (use MinBus to smooth transitions between time periods); g) implement and monitor; and h) recalibrate as needed to meet OTP targets.

Fleet Requirement and Assignment – Fleet assignments can have a significant effect on system operating efficiency. For this study, TMD reviewed vehicle group constraints by route, specialty bus type assignments, and garage capacities.

Seven vehicle types operate fixed route service from the Tempe and Mesa garages, including several specialty vehicles assigned to specific routes having restricted interline opportunities. "LINK" vehicles are assigned to LINK routes, with "ORIB" & "BUZZ" vehicles assigned to "Community Circulator" routes. "COMP" & "NX12" vehicles operate exclusively on "Express" routes and "ARTC" vehicles are assigned to both "Local" and selected "Express" blocks. "LC40" vehicles are assigned to "Local" as well as

[2] Current industry best practice calls for setting runtimes by a) targeting the 50-65 percentile operator performance; b) setting for cumulative timepoint runtimes (i.e., set A-B, then set A-C with B-C being the differential of A-C and A-B and so on); and c) setting recovery time based on ensuring that a percentage of the trips can start their next journeys exactly to the minute on-time (usually set at 95%). This approach achieves desired OTP performance with appropriate operator oversight and training in a balanced cost-effective and efficient manner.

"Downtown Circulator" routes. "ARTC" vehicles are assigned to blocks that are cut (to return to the garage) after the PM peak so they do not operate in the evenings where passenger loads are lighter.

There are no capacity issues at either the Tempe or Mesa garages and about two-thirds of the fleet is based at the larger Tempe garage. Garage distribution assignments are reviewed by Tempe staff and blocks can be reassigned based on proximity to route terminals (pull times and distances). It is not uncommon for routes to be split between garages. For maintenance and other purposes, certain specialty vehicles are assigned to a garage regardless of the proximity to the terminals. The use of MinBus can help define where changes to garage assignments and fleet distribution may balance and/or reduce peak vehicle requirements. With properly calibrated rules and parameters, Hastus MinBus is ideally suited for this task *but is not currently used*.

Tempe staff manually assign vehicle groups to blocks after the vehicle schedules have been transferred (by Phoenix staff) to the HASTEST database, and made available to Tempe staff. If using MinBus to generate blocking solutions, vehicle grouping constraints will be respected when interlining trips and assigning garages. Although vehicle groups can be assigned at the trip level, this can be a cumbersome process and it is easier to assign and manage vehicle groups when they are assigned at the route level (which can be overridden at the trip level if required). Currently, vehicle group information is not assigned at either route or trip levels. This would be necessary for MinBus to efficiently assign vehicles during the blocking process.

With properly calibrated rules and parameters, HASTUS MinBus is ideally suited for optimizing vehicle schedules and fleet assignment. It should be utilized to optimize each booking.

HASTUS Parameters – Establishing and fine tuning HASTUS rules and parameters, to optimize schedule performance and vehicle blocking efficiencies, is an essential component in the scheduling process. MinBus rules and parameters are used to direct trip linking, interlining, possible trip-shifting, garage assignment, pulls, deadheads, and travel activities. MinBus is a powerful tool for identifying opportunities to improve the efficiency and reliability of on-street operations.

Although Tempe staff often modify blocking solutions, they do not use MinBus for production scenarios. If rules and parameters were properly tuned then the tasks most commonly performed by Tempe staff (trip linking, interlining, trip shifting, and garage assignment changes), could be completed quickly and efficiently using MinBus.

It is recommended that the Tempe staff become familiar with and skilled in using the MinBus application. MinBus should be used to perform the blocking tasks now performed manually. However, process changes will need to be made and MinBus rules and parameters created to accomplish this. Reviewing and updating deadhead tables to reflect current conditions, defining vehicle types and groups as well as garage bus inventories and garage capacities, would allow MinBus to efficiently assign and/or reassign blocks to create daily vehicle assignments.

Future Contract Implications – Although the cities have third party service operating contracts (First Transit currently), changes to service, network design and vehicle scheduling provisions should be planned to improve the performance of future contracts. These changes should allow more efficient use

of operator resources, leading to lower costs as future contracts are negotiated.[3] While the contractor is compensated per revenue mile in the current contract, the efficiency of the operator runcut (contractor controlled) as well as the vehicle schedules (VM/Tempe/Mesa controlled) both influence the contracted cost per revenue mile. In fact, the runcut efficiency has significantly more impact on the contract cost (70% hourly based versus 30% mileage based). Therefore, it is in VM/Tempe/Mesa/VM's best interest to develop service and vehicle schedules that can be efficiently runcut.

The First Transit/ATU bargaining agreement and informal past practices, relating to driver assignments, were reviewed for potential cost savings. Current contract provisions appear to provide flexibility for daily and weekly assignments to be generated in a cost effective manner. A maximum spread of up to fourteen hours on weekdays, with no spread penalty, allows two peaks to be covered cost effectively by a single operator. Current indications are that the 55% weekday straight run requirement does not seem to be an impediment to the runcut efficiency.

The 1.43 peak to base ratio at the Tempe garage closely matches the 1.43 ratio at the Mesa garage. Both garages have a slightly higher PM peak requirement.

Although the straight run requirement on weekends is 100% (no splits), trippers are cut and allowed to be included in roster solutions. However, if 75% to 80% split duties were allowed, the trippers could be cut and matched as splits with higher work times. This may decrease the number of weekend duties and, in turn, reduce roster positions, as well as improve the runcut efficiency.

Split days off are allowed and are assigned to a limited number of roster positions. Several non-contractual, roster related concessions have been implemented which are intended to improve driver relations and, hopefully customer service. These concessions are minor and do not appear to have any negative impact on the roster solution.

Summary

The Service Design Review defined several areas of the scheduling process where efficiencies and improvements could be realized by modifying certain practices and fully incorporating and utilizing HASTUS tools. Tempe staff do skillfully use sound scheduling methods to create and implement scheduling solutions. Trips are re-blocked and interlined where possible to minimize vehicle requirements and are reassigned to appropriate garages where needed.

The more effective and regular use of HASTUS MinBus and ATP in the scheduling process, however, could increase productivity and efficiency in schedule production, on-street operation and overall cost. Realizing improved blocking solutions using MinBus will require implementing new blocking strategies as well as updating and maintaining appropriate sets of rules and parameters. A comprehensive, clean and valid set of on-street, point-to point runtime measurements is needed for reliable ATP analyses. The more valid data collected the more complete and dependable the ATP analysis will be. Recognizing that

[3] VM/Tempe/Mesa may wish to consider using a two or three part payment approach for future contracts that more fully reflect major cost centers and how those cost accrue and allow for more accurate and fair cost adjustments to service changes over the life of the contract. The suggested approach is a) hourly unit costs plus b) mileage unit costs (both of these are direct costs) plus c) fixed overhead costs (that do not usually change over the life of the contract).

the FY2014 on-time performance is just 61%, it is recommended this task be seriously considered. On-time operation is vital to the positive transit experience needed to attract and retain customers.

Recommendations (Short Term)

1. Minimize recovery time.
    a. Consider schedule efficiency in route design including seeking optimized alignment and round trip cycle time to minimize unproductive recovery time where feasible.
    b. Interline routes and trips to reduce bus requirements or improve reliability where optimal route design is not feasible.
2. Redefine on-time performance (OTP) to reflect just 1 minute early to 5 minutes late to reflect consumer needs.
3. Recalibrate running and recovery times by time of day and day of week to reflect actual street operations. With over 30% of service operating ahead of schedule, overall result should be tighter running times in the Southeast Valley.
    a. Address AVL data quality issues to assure that accurate data is available on an ongoing basis.
    b. Add circulator routes (ORBI buses) to the AVL covered services.
4. Build new weekday, Saturday, and Sunday schedules.
    a. Base on the recalibrated running and recovery times.
    b. Use HASTUS, especially MinBus, to maximum advantage allowing interlining and trip-shifting while respecting timed transfers.
5. Update Operating Contract parameters – introduce multiple unit cost drivers that better represent real costs in terms of hours and miles and fixed versus variable. Suggested for consideration are: variable cost per revenue hour, variable cost per revenue mile, and fixed administration/facility overhead.

Glossary of Terms

Blocking: The process of determining the sequence of trips a vehicle will make in the course of one day.

Booking: A new operating period with updated service schedules, vehicle blocks, and operator runs. Also known as a sign-up, bid, pick, or shake-up.

Cycle Time: The amount of time it takes a bus to get back to its starting location. This includes outbound and inbound trip running times and any recovery time taken before the start of the next trip.

Deadhead: This is be measured in hours and miles and refers to the time or distance a vehicle is in motion but not in passenger service. Usually deadhead occurs when a bus is traveling between the garage/dispatching facility and the start or end of the route, but also includes time and distance out-of-service between routes during an interline. Deadhead adds costs but does not generate revenue since passengers are not carried during this time. Therefore, efforts should be made to minimize deadhead where feasible.

HASTUS Parameters: HASTUS parameters can be split into hard and soft parameters. Hard parameters are parameters in the scheduling process that must be met due to contractual or physical constraints, such as a maximum number of hours for a work shift, or actual travel time to operate a particular route. Soft parameters are ideal features of a schedule that would improve the quality of the schedule but are not absolutely necessary. A soft parameter example is in MinBus where an interline is only considered where it will save a vehicle. These parameters vary by system and situation.

Interlining: Interlining improves resource efficiency by allowing one vehicle to operate multiple routes without going back to the garage. Typically, a vehicle finishing one route will continue on a different route either from the same or nearby terminal. This provides opportunities to improve efficiency by optimizing operator time and reducing vehicle requirements.

Peak to Base Ratio: This refers to the ratio of vehicles in service during peak hours compared to the vehicles in service during off-peak (base) hours.

Platform Hours: The total time a vehicle is on the road. This includes deadhead, running, and recovery (layover) time.

Recovery (Layover) Time: A short period of time taken at the end of the route for vehicle operators to take a rest break (operator layover) and to provide a time "cushion" to ensure that the next trip leaves on-time (schedule recovery). Confusion over who "owns" this end-of-line time (the operator or the schedule) is a contributor to lower OTP.

Revenue Hours: The time a vehicle is in passenger service. This includes running time and recovery time, but does not include deadhead time.

Run Cut: A run is the schedule of trips that an operator drives in one day. The runcutting process takes the blocks assigned to vehicles and cuts them into daily assignments, i.e."runs" for vehicle operators.

Runs usually are divided into two categories: “Straight” Runs (one continuous shift) or “Split” Runs (a shift is split over multiple periods of time separated by a break where the operator does not work).

Running Time: The time it takes a vehicle to operate each one-way trip. This usually varies by time of day and day of week due to changing roadway traffic and passenger loading conditions. Running time is also known as “in-service” time and does not include layover/recovery or deadhead time.