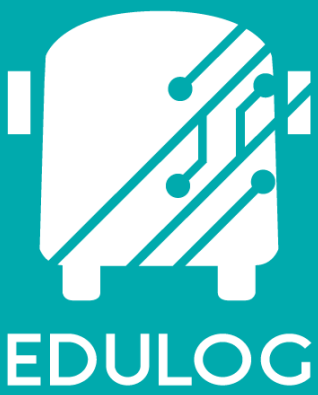

Transportation Optimization Study

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(406) 728-0893

April 2019

REPORT TO:

LEON COUNTY SCHOOLS

Leon County Schools, Florida

Performed and Presented by:

EDULOG
CONSULTING

TRANSPORTATION OPTIMIZATION STUDY

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Executive Summary

Edulog was engaged to conduct a Transportation Study on Leon County Schools to investigate the following questions:

(1) What is the potential impact of a run optimization of the current three-tier transportation model?
(2) What is the potential impact of a route optimization of the current three-tier transportation model?
(3) What is the impact of moving from a three-tiered bell time schedule to a two-tiered bell time schedule?

The scope of the investigation of all three questions was defined to include transportation-eligible general education students attending 44 schools/programs (including two IB schools). The scope defined by Leon County Schools specifically excluded Exceptional Student Education ("ESE") students, due to the high level of individualization and variability of ESE transportation, both of which introduce data noise in any comparative impact study.

Leon County Schools directed Edulog to use a specific subset of buses for analysis in the study as shown below:

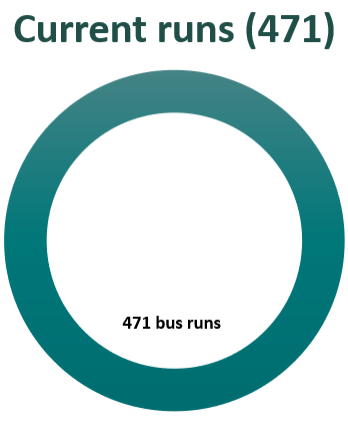
		Study-Specific Cap.		
Vehicle Cap.	**Veh. Count**	**ES**	**MS**	**HS**
66	4	62	52	43
71	25	67	57	47
72	33	67	57	47
78	29	74	63	53
81	84	76	65	55

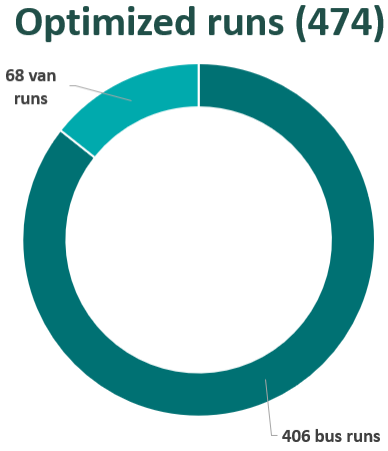
Edulog was further directed to consider the addition of 21 8-passenger vans which would be used exclusively to serve the two IB schools (Fairview MS and Rickards HS).

Leon County Schools currently uses its AS400 route management system as its primary student data repository. The data and structure of the AS400 system housed a number of data irregularities that required correction before Edulog could perform its study. Among the data elements cleaned, pared and organized were school locations, transportation eligibility, and hazard, attendance and walking boundaries.

Run/Route Optimization

Edulog's run optimization, keeping constant the current three-tier bell time schedule, but adding 21 vans to exclusively serve the 2 IB schools, produced a result of 474 runs compared to the district's current 471 runs. **The optimization reduced the number of *bus runs* from 471 to 406.**





Drawing a straight comparison between the run numbers in the current state and the optimized state is misleading; the current runs are currently 100% served by buses, and 22% of the current runs (representing over 50% of routes) had negative slack, with the average amount of negative slack being over 60 minutes/run. The Edulog-optimized run/route data eliminated negative slack and includes a significantly different complement of vehicles.

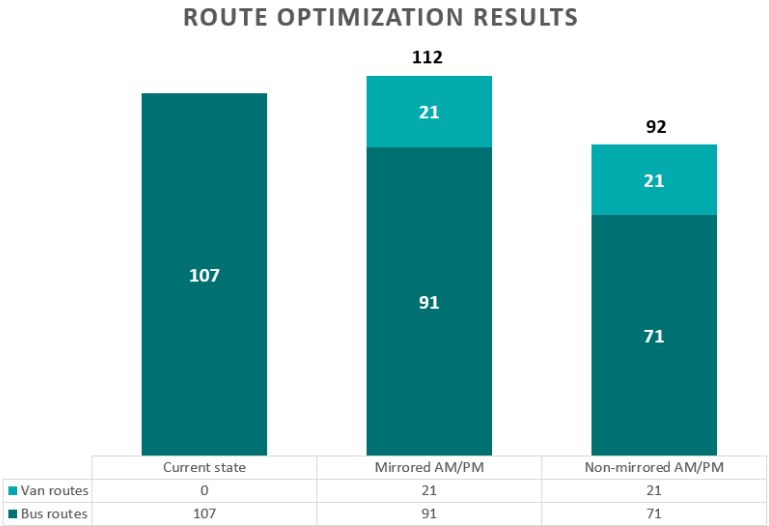
The run-level optimizations followed a simple-yet-strict set of rules. The summarized list of rules follows below:

- Maximum Ride of 60 minutes in both the AM and PM periods.
- Only include stops where students are eligible and assigned to services.
  - Ignore any zero-load stops
- Utilize assigned loads for run-building.
  - Follow school-level capacities listed in the above section ("Defining Buses for Study Data").
- Run mirroring must exist for the AM and PM periods.
  - Stop sequences for individual AM runs are reversed in the PM runs.

Excluded from the optimization were runs meeting one or more of the following conditions:

- Runs servicing schools not included in the study
- ESE runs – marked with .5 or .6 run codes
- Runs with frequencies other than MTWUF
- Runs that do not have route assignments
- Runs that contain no assigned or headcount loads
- Routes with no runs assigned

With full route mirroring, Edulog's route optimization combined the 474 optimized runs into 112 routes, representing a ***net decrease of 16 bus routes*** (with 21 8-passenger vans serving IB routes) compared to Leon County's current 107 bus routes. The *overall* increase in routes from 107 bus routes currently to 112 routes in the optimized mirrored solution is attributable to Leon County's addition of the 21 8-passenger vans into the optimized solution. If no mirroring is required, the routes could be further optimized down to 92, ***a net decrease of 36 bus routes***.

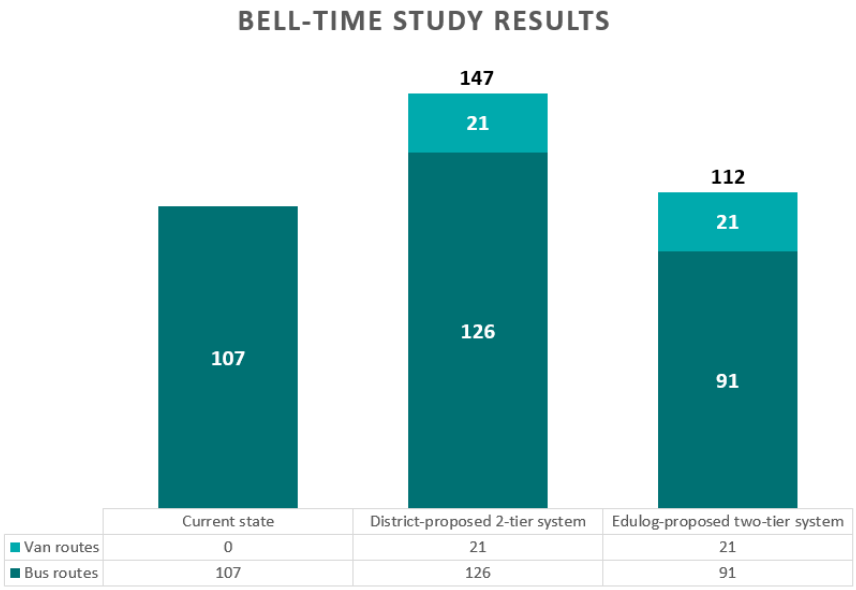


The optimization study results in some mileage savings. However, as with the run/route comparisons, the mileage incurred in the optimized solutions is affected not only by the optimization itself but also by the addition of the 21 8-passenger vans to the fleet. Adding vans to transport IB students adds a significant amount of mileage to the totals. Under the current model, IB students are transported on existing regular-education runs, and many of these runs can easily accommodate them into their current loads (with minimal time/distance penalties). By contrast, deploying a separate fleet of vans eliminates the advantage of the regular bus, since the low load capacity (8-person), and the fact that IB students are *outside of their posted attendance boundary* mean that these van runs are numerous, take more time, and travel farther distances. The table below illustrates the mileage savings between loaded miles driven in the current scenario compared to loaded miles driven in the mirrored optimized solution.

Loaded Mileage - Final Comparison						
Category	**Total Miles**	**AM miles**	**PM miles**	**Avg - Total**	**Avg - AM**	**Avg - PM**
Current	6894.95	3432.08	3564.87	14.63	14.61	14.67
Total Run Opt	6527.52	3236.31	3291.19	13.77	13.71	13.83
Difference	-367.43	-195.77	-273.68	-0.86	-0.9	-0.84

Bell-Time Study

The Bell-Time Study utilized the optimized run data to simulate moving from a 3-tiered routing system down to only two. All-combined, the district-recommended approach (splitting the Middle School tier) generated 147 total routes, with a net increase of 19 bus routes, while ***an Edulog-designed alternative approach to the 2-tier system generated 91 bus routes, a net decrease of 16 bus routes compared to the current model***. Comparing both solutions against the current transportation model, the district-led approach led to an increase in total routes by 40 routes, while the Edulog approach increased the total by a more modest 5 routes. The overall increase in total routes between the current state and either of the two-tier schedules is attributable to Leon County's addition of 21 8-passenger vans to transport IB students.



None of the solutions reviewed exceeded Leon's current bus inventory:

	Route Opt		Bell-Time Study	
Opt Results	**No Mirroring**	**Yes Mirroring**	**01: District Bells**	**02: Edulog Bells**
Optimized Regular	71	91	126	91
Optimized Vans	21	21	21	21
Total Opt	92	112	147	112
Bus Fleet Type				
81-passenger Bus	71	81	81	81
78-passenger Bus	0	10	29	10
72-passenger Bus	0	0	16	0
8-seater Van	21	21	21	21
Total Opt	92	112	147	112

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Section I – Background

In January 2018, Edulog conducted an assessment on the transportation department for Leon County Schools. That assessment discovered that Edulog was a secondary program to the AS400 system the district had been using to house student-level details and to generate annual state reports. The assessment also discovered that data in the Edulog system relating to hazard, school attendance, and walk boundaries were inaccurate.

In June of 2018, all of the boundaries for attendance and hazards were corrected via Maris, while walk boundaries were recreated as some of the schools were not located in the correct location. This work was verified by Marsha at Leon County Schools, who had the most knowledge of all the boundaries.

As the assessment continued, Leon County School requested a bell-time analysis of their route-tiering structure. Student information from the October 2018 State Report (generated from the AS400 data) was provided to Edulog, where students were defined by their “active rider” status. The AS400 data was the baseline for the eventual optimization, and its limitations were compared against the newly-corrected boundaries.

Leon County Schools has courtesy transportation, meaning that students may ride the bus even if they are not eligible. Limitations within the AS400 system prevent accurate transportation eligibility record-keeping in the state report. As a result, a number of non-eligible riders were included in the report, including students inside of walk boundaries and outside of school attendance zones.

Edulog endeavored to assign accurate eligibility to students for the purposes of the optimization study. Assignments were based upon the newly-corrected hazard, walk, and school attendance boundaries. Students that did not qualify for transportation per Leon County Schools’ official policies were not given a ridership, following the best practices with Edulog Advanced.

Section II – Routing Efficiency

Efficiency is doing the most with the least amount of resources. In the most general sense, in terms of pupil transportation, this means transporting the most students with the least amount of buses. There are a number of constraining factors in achieving this goal, as well as other priorities that may alter a specific district's definition of efficiency. Each district has different constraints and priorities, based on geography, politics, students, etc. However, there are a few widely accepted Key Performance Indicators (KPIs) that allow for comparison from district to district.

A measure of the efficiency of the overall routing is the number of runs per route, which can be expressed as:

$$\rho = \frac{\text{Number of } Runs}{\text{Number of } Routes} \quad ,$$

A standard for efficiency would be expressed as six runs per route, or one run for each tier for morning and afternoon service, assuming there are three tiers for morning and afternoon. Under real world conditions, this is unrealistic to expect, so it is illustrative to look at the overall distribution of the number of runs on each route. Ideally, this would have a normalized distribution, or follow a bell curved shape, with the mode, or most common number, falling at or near six runs per route.

An additional useful metric is the number of students transported per route during the morning and afternoon services. This can be expressed as:

$$\theta_{am} = \frac{Number\ of\ Students\ Transported_{am}}{Number\ of\ Routes_{am}} \quad ,$$

and similarly for PM routes. In an efficient routing system, with perfect tiering, a route would be comprised of at least six runs (possibly more, depending on a number of factors, but for this purpose, we will assume six, one for each tier in the morning and afternoon). Given an average bus capacity of fifty students, an excellent score on this metric would see 150 students transported during each service.

In order to achieve an efficient transportation model, buses must be run as full as possible. A useful measure of capacity usage is the average ridership per bus, which can be expressed as:

$$\alpha = \frac{Number\ of\ Students\ Transported}{Number\ of\ Runs},$$

This metric is limited by the individual capacity of the bus, which differs based on the age of the students, so a separate calculation for each load capacity may be useful. In this case, bus capacities were set conservatively as noted below. It costs the same to operate a bus regardless of how many students are transported, so in order to fully utilize the fixed asset, capacity should be as high as possible while still allowing for feasible runs under the maximum allowed time frame.

Section III –Optimization Study Parameters

The success of any Optimization Study is reliant on the quality of the underlying transportation data. Conversations with the District produced an agreement on the scope of work, which determined how the study was conducted and how results are presented in this report. Information from this section onward concerns only the transportation data included in the study.

Scope of Optimization Study

During the preparatory stages of the study, Edulog worked with Leon County Schools to validate and prepare their Edulog data for optimization, which centered upon stop assignments of eligible riders from their October 2018 State Report. For the study itself, Edulog conducted an assessment on Leon County's current student/stop data for a specified list of schools, and then optimized runs for both the AM and PM periods. A route schedule was constructed along current bell-times, followed by a Bell-Time analysis to determine what the impacts would be were the district to move from a three-tiered system to only two tiers.

There were a number of assumptions and constraints that have to be taken into account during an optimization. The most important, which has been expressed by Edulog throughout the process, is that this is a study based upon data selected by Leon County Schools during the scoping phase. Runs and routes generated are based on a snapshot of the district's data at a single point in time, and do not reflect updates to the data since that date. In this case, the study data was given to Edulog on February 18th, 2019. The results of this study are not road-ready to be implemented. Rather, it serves to show the potential for implementing a number of scenarios that estimate impacts to transportation.

Students: Eligibility and Active Ridership

Students selected for the study were defined by their ridership eligibility in the Annual Florida State Report, generated in October 2018. This report was built using data from the district AS400 route management system rather than through the Edulog software. The district follows a policy of courtesy transportation, meaning that students were assigned transportation regardless whether they rode or not. Through a process of validation and correction, the state report was utilized to determine active ridership vs. eligibility. Data in Advanced was subsequently uploaded and modified to reflect actual stop loads for use in the study.

Defining Buses for Study Data

Leon County Schools directed Edulog to use a specific subset of buses for analysis in the study. A total of 175 vehicles were available for inclusion in the study, and governed how the routes were built. The table below shows the breakdown of available vehicles:

		Study-Specific Cap.		
Vehicle Cap.	**Veh. Count**	**ES**	**MS**	**HS**
66	4	62	52	43
71	25	67	57	47
72	33	67	57	47
78	29	74	63	53
81	84	76	65	55

In addition to the vehicles reflected in the table above, Edulog was directed to apply unique scenarios to 2 individual schools: students outside of the attendance zones for Fairview MS and Rickards HS were to be transported using 8-person vans. There was no limit set for these vehicles, and runs were optimized using the same parameters for that school. The optimization study results indicate that transportation for Fairview MS and Rickards HS can be achieved with 21 8-passenger vans.

Run Optimization

Parameters that governed the run-level optimizations followed a simple-yet-strict set of rules. The summarized list of rules follows below:

- Maximum Ride of 60 minutes in both the AM and PM periods.
- Only include stops where students are eligible and assigned to services.
  - Ignore any zero-load stops
- Utilize assigned loads for run-building.
  - Follow school-level capacities listed in the above section ("Defining Buses for Study Data").
- Run mirroring must exists for the AM and PM periods.
  - Stop sequences for individual AM runs are reversed in the PM runs.

Edulog was given latitude over details governing the algorithm, which prioritized the time and load-capacity limits over the deadhead calculations.

Route Optimization

The standard Route Optimization utilized Bell Times that already existed in the Edulog data, which was entered by the district and reflects current starting- and end-times. The most important rule governing the optimization was to follow the vehicle requirements discussed in "Defining Buses for Study Data", so that only preexisting buses were being used. No route mirroring was required for the end solution.

Bell-Time Optimization

For the Bell-Time Study, the primary goal centered on the move from a three-tiered routing solution (that is currently run by the district), down to a two-tiered system. Edulog was instructed to maintain the length-of-day for all schools for the final solution, with a guiding principle of having an hour gap between each of the tiers to allow sufficient space for deadhead time.

For the Bell-Time analysis, two different approaches were employed. The first scenario used bell-times and tiering structures requested by Leon County Schools, while the second scenario followed an approach laid out by Edulog. The table below describes each approach employed for the study:

	Description	Tier	AM Bells	Schools
Scenario 01	District Approach	1	7:50	All High and 5 Middle
		2	8:50	All Elementary and 3 Middle
Scenario 02	Edulog Approach	1	8:15/8:30	All Elementary
		1.5	9:00	Nims MS
		2	9:30	All High and 7 Middle

Current bell times were shifted for each scenarios, with the arrival and departure windows for Elementary, Middle and High Schools remaining at their same relative lengths. The guiding principle here was to minimize the total impact of bell-time shifts while seeking to build the most-efficient routes.

Note that Edulog's approach suggests a later relative start time for the high schools. This follows the trend observed in districts around the country flipping elementary schools/middle Schools and HS start times to accommodate high-schoolers' circadian rhythms. However, we also know that in many districts, starting high schools later has caused unintended consequences relating to high schoolers' ability to maintain expected/desired levels of involvement in after-school sports and other extra-curricular activities. The impact of the Edulog approach on high schools could be mitigated by sliding the whole schedule to the left (i.e., elementary bell time at 7:45). As long as the gap between the tiers stays the same, the analysis still holds.

There is a third possible bell time scenario, which is a variation on a flipped version of the Edulog approach, and allows the High School/Middle School bell to be first, followed by the Elementary bell, and Nims on its own tier. The Edulog approach cannot simply be flipped, because it isn't clear that the High School/Middle School tier and the Elementary tier are sufficiently similar to each other. The work to prove out this concept can be performed under a new scope of work if Leon County Schools is interested in exploring this option further.

Exclusion of Exceptional Student Education ("ESE") transportation

Transportation for ESE programs occurs daily, and makes up a significant portion of the Other District School runs that the district provides in- and out- of the district. These buses and runs were excluded from the study due to the fact that ESE transportation is highly individualized and is frequently changing versus non-ESE students. Their exclusion here was warranted for the purpose of achieving better impact estimates.

Use of Frequencies

All schools and runs that were included in the study make use of the standard MTWUF—frequency in the EDULOG data, and no changes were made to the standard operating frequency during the study.

Section IV – Current Transportation Model

Schools and Bell-Times

Leon County Schools currently provides transportation for a large number of schools and programs across the district. The scope of this study was defined to include only the 44 schools/programs appearing in the table below, with the Other District Schools grouped together:

Type	School Names
ES	Hartsfield , Sabal Palm , Oak Ridge , Bond , Sullivan , Ruediger , Woodville , Riley , Pineview Elem, Gilchrist , Astoria Park , W.T. Moore, Sealey , Apalachee , Killearn Lakes , Chaires , Springwood , Desoto Trail , Buck Lake , Ft Braden , Hawks Rise , Canopy Oaks , Roberts , J Michael Conley
MS	Nims , Cobb , Raa , Griffin , Fairview , Deerlake , Swift Creek , William J, Montford
HS	Godby , Leon , Rickards , Lincoln , Lawton Chiles
Other District Schools	Sail, Governor's Charter, Success Academy, Gretchen Everhart School, Heritage Trails, Second Chance/ Ghazvini Learning Ctr

Leon County Schools currently utilizes a three-tiered system for both the morning and afternoon periods. The current bell-times by tier and type are as follows:

		AM		PM	
Tier	School Group	Arrival Window	Bell-Time(s)	Bell-Time(s)	Depart Window
1	High	30 min.	7:25, 7:30	1:50, 2:00	30 min.
2	Elementary	30 min.	8:15, 8:30	2:50	30 min.
3	Middle	30 min.	9:00, 9:30	3:50	30 min.

Bell times for non-public schools/programs vary widely across the entire dataset. For the purposes of this study, their times may be summarized as follows:

	Bell-Time Ranges for Non-District Schools
AM	7:30 AM - 9:30 AM
PM	1:30 PM - 3:50 PM

Details on bell-times for both the district and Other District Schools included in the study can be found in Appendix B at the end of this report.

Runs and Routes

Summaries of Leon's current transportation data excluded runs if they met one or more of the conditions:

- Runs servicing schools not included in the study
- ESE runs – marked with .5 or .6 run codes
- Runs with frequencies other than MTWUF--
- Runs that do not have route assignments

- Runs that contain no assigned or headcount loads

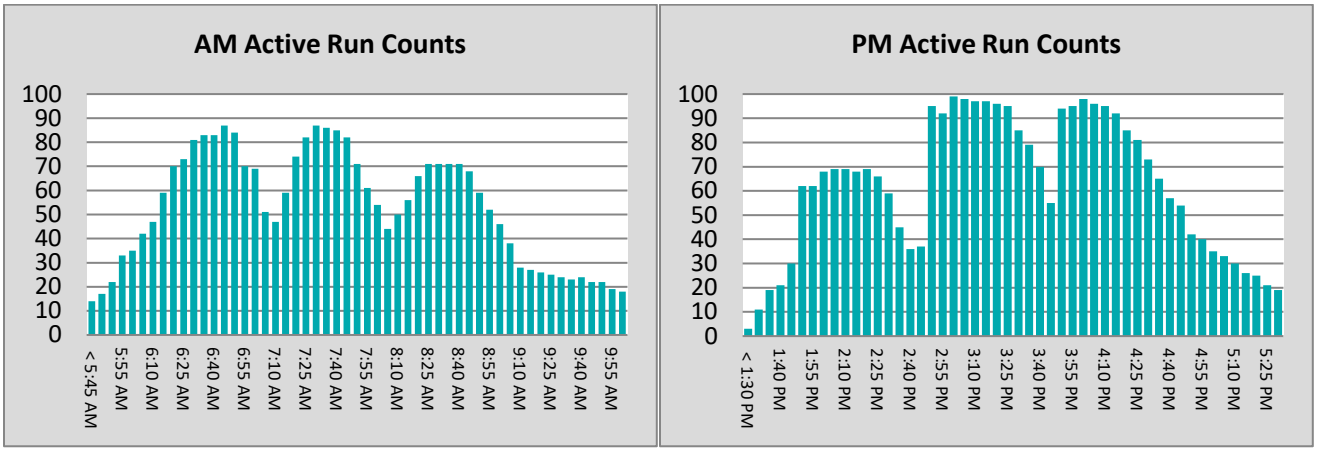
Routes without any runs assigned to them were also removed from the analysis. These criteria were applied to reduce the amount of noise and inaccuracies within the data, and for conducting accurate comparative analyses later in this report. Since transportation for the IB students was an exploratory study request, no van runs existed within the data, and those students were captured in the current run data.

As a result of all this, a total of 471 runs remained in the data that fit within the study parameters. A breakdown of the runs can be seen in the below table:

		AM	PM	Total
Totals	Run Count	235	236	471
	Loaded Run Time	14333	17501	31834
	Loaded Distance	3736	3673	7409
Averages	Avg. Stops per Run	14.6	14.9	14.8
	Avg. Students per Run	48.2	47.9	48.1
	Avg. Loaded Run Time	69.2	74.8	71.9
	Avg. Loaded Distance	15.9	15.5	15.7

Student and stop totals have been excluded here because that data used for the study comes from the AS400 reporting system and is based upon October 2018 FEFP ridership. A more-detailed summary of the study data is provided later on in the report in Section V.

The totals and averages for both the loaded run time and run distance columns are notably high in this case. It should be noted that this is partially attributed to calculation errors amongst certain runs. Active run tallies for both the AM and PM periods can be visualized in the charts below:



While the obvious errors were omitted from the summary stats, there were also a number of runs that were unusually long, yet it wasn't entirely clear that it was directly attributable to missing segments in the geocode. These long runs are most noticeable in the tails of each distribution, such as the latter part of the AM period.

The routing system based upon the 3 tiers of runs brings the total number down to 107 routes with assigned runs. A breakdown of the route data can be seen in the below table:

	AM	PM	Total
Total Assigned Routes	103	103	107
Avg. Runs-per-Route	2.29	2.28	4.41
Total Deadhead Time	1342	1464	2806
Total Deadhead Distance	758.8	748.4	1507.2
Avg. Deadhead Time	13.0	14.2	26.2
Avg. Deadhead Distance	7.4	7.3	14.1

Notice how despite there being 103 utilized routes for both the AM and PM periods, there are a total of 107 routes used throughout the day. This can be attributed to the crowding of runs that occurs across the three tiers due to run length and the number of schools serviced. For example, there are 24 routes that have 1 district run assigned to them in the AM, and 23 routes in the PM facing the same issue. When compared across the entire day, there are 27 routes with 2 or fewer runs assigned to them. It also brings down the average runs-per-route values to less than 2.5, and reduces the overall efficiency of bus utilization.

Distance and time values in the data were not impacted by calculation errors, and are considered to be more accurate than distances and times for the loaded run sections. Discussion about the geocode, concerns about negative slack, and their relationship to the study are more thoroughly discussed in Section V.

Section V – Assessment of Study Data

As part of any Optimization Study, Edulog first assessed the quality of the district's data within the system. This was done to identify potential data issues that may affect the ability of Edulog to conduct a successful Optimization Study, so those issues can then be addressed and fixed. Conducting an assessment also gives Edulog and the District a broad picture of the study data and identifies potential limiting factors with the optimization. The previous section focused on their current transportation setup, in particular the run and route data not included in the study itself. This section outlines the data utilized for optimizations in the study.

Map Accuracy & Negative Slack

Leon County's map within the Edulog system appeared to be reasonably calibrated, meaning that system generated run and stop times are largely feasible. Comparative analysis on current run and route data did discover a few distance and time calculation errors, but they were not widespread enough to halt the assessment. Any further calculations errors that would crop up in the results were addressed later on, and did not negatively impact the final solutions.

Despite the fact that current runs and routes were not included in the baseline, concerns arose regarding their negative slack. A raw breakdown of the negative slack is shown in the table below:

	AM	PM	Total
Total Runs w/ Negative Slack	42	63	105
Runs ≤ -10 min. Slack	15	20	35
Runs ≤ -30 min. Slack	29	42	71
Runs ≤ -60 min. Slack	37	49	86
Total Routes w/ Negative Slack	37	43	58
Total Negative Slack	-2231	-4498	-6729
Avg. Neg. Slack - By Run	-53.1	-71.3	-64.1

While a percentage of the negative slack calculations are due to calculation errors, it is critical to note that the number of runs below the -10, -30, and -60 mark support the view that they are a minority. This amounts to ~54% of the total routes assessed in the previous section, and ~22% of the total run count. Because of this, it was concluded that the district's geocode is relatively slow compared to conditions on the road. No adjustments were made to run lengths during route optimization, and it can be assumed that individual run lengths for the optimized data are on the conservative side.

Negative slack shows evidence of infeasibility in a routing system, meaning that there is not enough time to make connections between planned runs. Sometime these connections may work in reality, but they do not technically work within Edulog because there is not enough time between runs as determined by the geocode. A map that is properly calibrated with accurate speeds will allow users to generate the most consistent, best results within the system.

Schools & Bell-Times

In the study data, Leon County Schools currently provides transportation for 44 schools/programs. To re-summarize these schools, a breakdown of them by category is shown in the table below, with Other District Schools grouped together:

Type	School Names
ES	Hartsfield , Sabal Palm , Oak Ridge , Bond , Sullivan , Ruediger , Woodville , Riley , Pineview Elem, Gilchrist , Astoria Park , W.T. Moore, Sealey , Apalachee , Killearn Lakes , Chaires , Springwood , Desoto Trail , Buck Lake , Ft Braden , Hawks Rise , Canopy Oaks , Roberts , J Michael Conley
MS	Nims , Cobb , Raa , Griffin , Fairview , Deerlake , Swift Creek , William J, Montford
HS	Godby , Leon , Rickards , Lincoln , Lawton Chiles
Non-District	Sail, Governor's Charter, Success Academy, Gretchen Everhart School, Heritage Trails, Second Chance/ Ghazvini Learning Ctr

The transportation setups for school start- and end-times follow a 3-tier structure. A breakdown of the bell-times by tier can be found in the table below:

		AM		PM	
Tier	School Group	Arrival Window	Bell-Time(s)	Bell-Time(s)	Depart Window
1	High	30 min.	7:25, 7:30	1:50, 2:00	30 min.
2	Elementary	30 min.	8:15, 8:30	2:50	30 min.
3	Middle	30 min.	9:00, 9:30	3:50	30 min.

Students & Stops

There were 10,641 total students uploaded into the dataset from the October FEFP report. Once they were in, students were assigned transportation based on eligibility for attendance, walk-to-school distances, and existing hazard zones. The following table is a shortened summary of the totals included.

Student Totals - Category	Count
All "Y" RIDER	10641
Eligible	8109
Not Eligible	2537

The 8,109 total also includes students attending the Rickards/Fairview “IB” program outside of their respective school’s posted attendance boundary. A closer look at the 2,537 excluded students yields the following breakdown of eligibility codes:

Excluded Students - Category	Count
Outside of Attendance Zone	624
Inside Walk-to-School Zone	1913
Total	2537

Moving on to stop assignments, the following table shows the breakdown of total assigned stops by their AM-PM service:

Stop - Category	Count
AM service	2158
PM service	2263
Total stops serviced	2762

Existing stops were utilized for the batch assignment process, and if a student existed outside of the walk-to-stop distance they were given home stops assignments. In the case of students attending the IB program at Rickards HS and Fairview MS, home stops also had to be created for these students, as they existed outside their respective attendance boundaries.

Section VI – Optimization Study Results

Overview of Results

A summarized table of results from the run-level optimization is presented below:

Run and Route Opt				
Category	**Total Routes**	**Total Runs**	**AM Runs**	**PM Runs**
Optimized Regular	71	406	203	203
Optimized Vans	21	68	33	35
Total Opt (no mirroring)	92	474	236	238
Current	107	471	235	236
Difference	-15	+3	+1	+2

The route-level optimizations and bell-time studies can be combined into a second table of results. The totals for each scenario and their comparisons can be viewed in the below table:

Route and Bell-Time Opt		
Results	**Total Routes**	Total Change
Current	107	-
Route Opt - No Mirroring	92	-15
Route Opt - Yes Mirroring	112	+5
Scenario 01 - District Approach	147	+40
Scenario 02 - Edulog Approach	112	+5

Run Optimization

In the study data, Edulog produced a solution containing a total of 406 runs servicing the 44 schools/programs, for both the AM and PM periods combined. An additional 68 runs were generated to service the IB students utilizing vans with 8-seat capacities. A breakdown of the regular-bus runs are presented in the below table:

		AM	PM	Total
Totals	Run Count	203	203	406
	Assigned Stops	2158	2263	2762
	Assigned Students	8038	7996	8109
	Loaded Run Time	5351	5683	11034
	Loaded Distance	2758	2820	5578
Averages	Avg. Stops per Run	11.2	11.9	11.5
	Avg. Students per Run	44.7	45.2	44.9
	Avg. Loaded Run Time	26.4	28.1	27.2
	Avg. Loaded Distance	13.6	13.9	13.7

An important note regarding the optimized run data are the high average load counts running alongside relatively-low run times. Leon County's predominately urban/suburban topography allowed a majority of bus

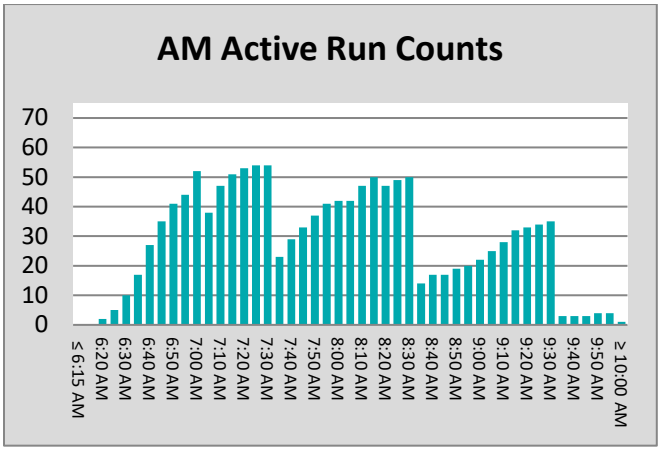
runs to fill to capacity well before they reached their time limits. Runs closest to the 60-minute mark consequently have the highest loaded mileage as well, including the vans servicing students in the IB program.

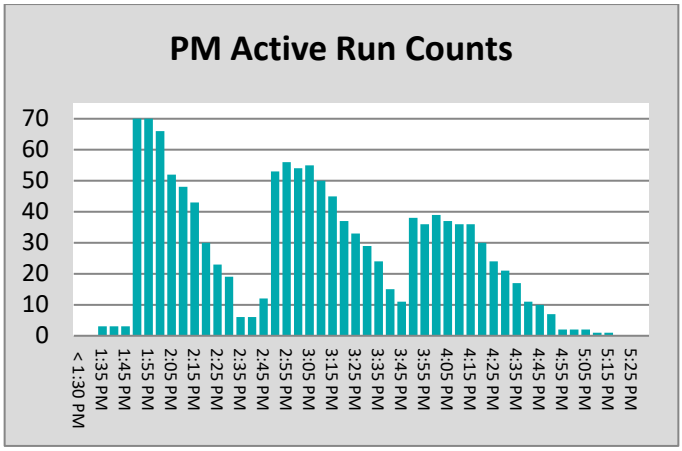
And since the IB students are serviced external of the regular-bus transportation, a shortened summary table of the van runs has been included below:

	AM	PM	Total
Total Van Runs	33	35	68
Avg. Stops per Run	7.8	8.0	7.98
Avg. Students per Run	7.4	7.0	7.2
Avg. Loaded Run Time	36.4	29.3	32.7
Avg. Loaded Distance	14.5	13.5	13.9

Route Optimization

For the Route Optimization phase, the optimized run data was put through two separate scenarios. The first one allowed for runs to be assigned to routes based on achieving the most efficient route-level solution. The second one required that runs between the AM and PM periods be mirrored on their respective routes. The two charts below detail active run counts across both the AM and PM periods, dividing into 5-minute bins.





While a policy of mirroring can impact a route solution, the runs themselves do not change their respective bell-times and run lengths. Detailed charts using the current bell-times can be found in A.1 and A.2 in the appendix.

The van routes servicing IB students were done prior to running both route-coupling optimizations, and resulted in a total of 25 total routes. In the table below, we can see their route-level information summarized:

	AM	PM	Total
Total Assigned Van Routes	19	19	21
Avg. Runs-per-Route	1.73	1.84	2.7
Total Deadhead Time	94	335	429
Total Deadhead Distance	189	171	360
Avg. Deadhead Time	5.7	9.6	7.7
Avg. Deadhead Distance	2.86	4.9	3.9

Below are the results for both route-coupling optimizations concerning regular-bus transportation:

Full-Opt Scenario (Non-Mirrored)

In the fully-optimized non-mirrored scenario, a total of 71 bus routes were generated using the 406 optimized runs along current bell-times. A table summarizing the bus route-level data is provided below:

	AM	PM	Total
Total Assigned Routes	71	71	71
Avg. Runs-per-Route	2.89	2.86	5.71
Total Deadhead Time	1704	2449	4153
Total Deadhead Distance	926	1472	2398
Avg. Deadhead Time	8.4	12.1	10.2
Avg. Deadhead Distance	4.6	7.3	6.1

Mirrored Scenario

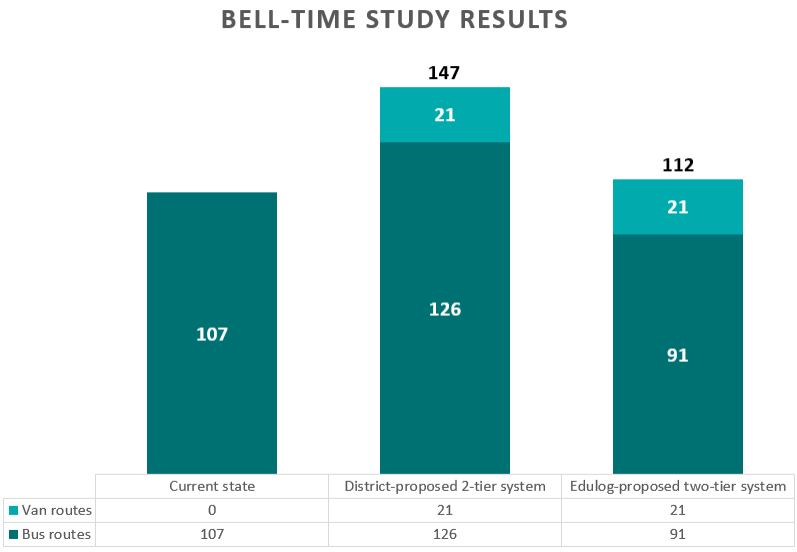
In the scenario with the full route-mirroring requirement, a total of bus 91 routes were generated at an increase of 20 bus routes compared to the no-restrictions scenario above. A table summarizing the route-level data is provided below:

	AM	PM	Total
Total Assigned Routes	91	91	91
Avg. Runs-per-Route	2.23	2.23	4.46
Total Deadhead Time	2057	3257	5314
Total Deadhead Distance	1209	2064	3273
Avg. Deadhead Time	10.2	16.1	13.1
Avg. Deadhead Distance	5.6	10.2	8.1

Bell-Time Optimization

Route and Bell-Time Opt Results	Total Routes	Total Change
Current	107	-
Route Opt - No Mirroring	92	-15
Route Opt - Yes Mirroring	112	+5
Scenario 01 - District Approach	147	+40
Scenario 02 - Edulog Approach	112	+5

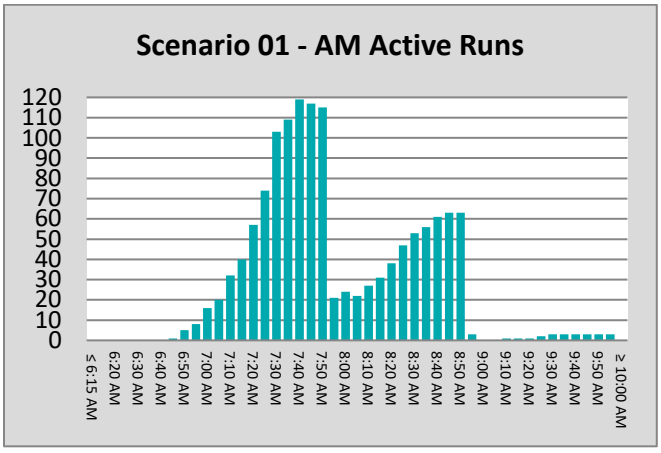
In the Bell-Time Analysis, Edulog first used Leon County's proposal for approaching the 2-tiered optimization. In addition, a separate bell-time scenario was conducted using an alternative method of condensing the 3 pre-existing tiers down into two. For more details on each approach, please refer to the "Optimization Study Parameters" earlier in this report.

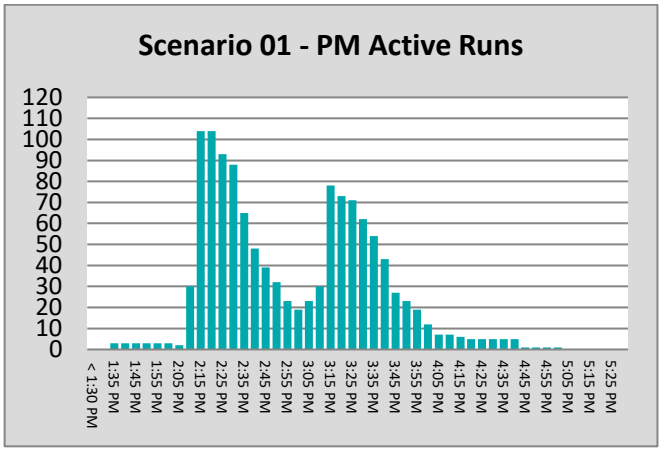


Scenario 01 – District Approach

Using the district's recommended approach to the bell-time study, collapsing 3 tiers into a 2-tiered solution yielded 126 regular bus routes in optimization. When we include the 21 additional van routes, it results in a total of 147 routes. This is a relative increase of 19 buses (40 additional vehicles overall, if the 21 vans are included) as compared to the current transportation model (107 buses), and 35 more buses than the mirrored optimized solution using current bell-times (91 buses).

Two short graphs have been provided below to illustrate the active run counts for both the AM and PM periods for non-van optimized runs:





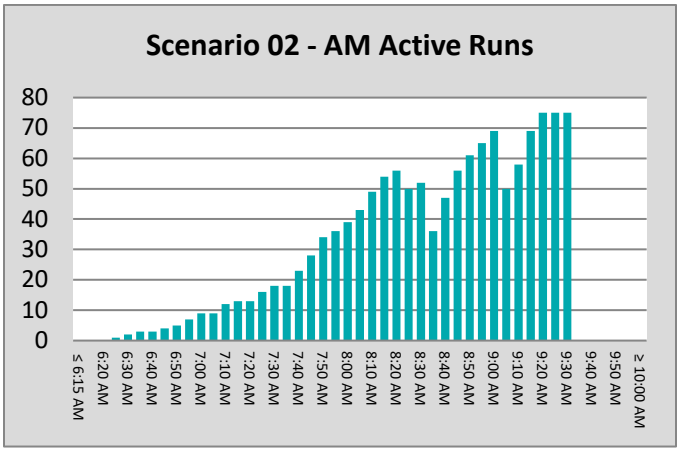
To see both of these graphs in large-size and with greater details, please refer to figures A.3 and A.4 in the Appendix. From what we can visualize here, the largest constraint on the scenario lies in tier 1 during the AM

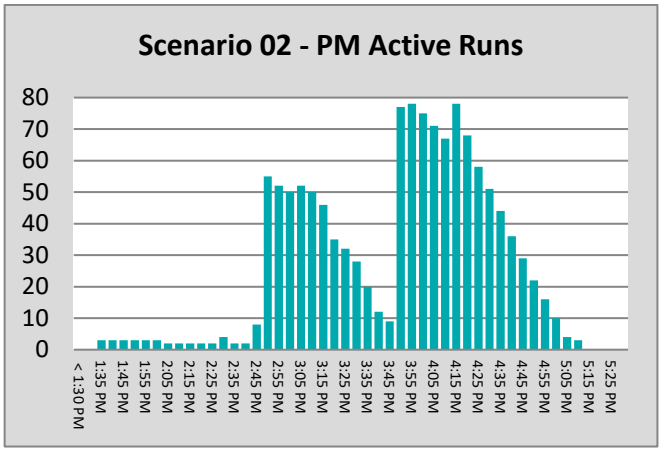
period. A 15-minute stretch between 7:35 and 7:50 AM shows an active run count well over 110 runs, peaking at 120 during the 7:40-7:45 time. Comparing this to the optimized runs pre-bell opt shows a drastically different picture than the 3-tier system the district currently uses. The Other District Schools and programs were left static for the bell-time scenario, as evidenced by the long tails in each AM/PM distribution.

Scenario 02 – Edulog Approach

Upon examining the results of Leon County's recommended approach, another scenario was conducted using an Edulog approach to splitting the three tiers.

This approach resulted in a total of 112 routes when the 21 additional van routes have been included, a net increase of 5 routes compared to the current transportation model (but 16 *fewer* bus routes). Compared to the non-mirrored route solution using current bell times, this optimized Edulog two-tier schedule results in a net increase of 20 routes (all buses), and no net change when comparing with the full route-mirrored optimized solution using current bell times. Two short graphs have been provided on the following page to illustrate the optimized non-van run counts for both the AM and PM periods:





To see both of these graphs in large size and with greater details, please refer to figures A.5 and A.6 in the Appendix. In contrast to Scenario 01, the largest constraint here lies in tier 2 during the PM period. The multiple peaks in the second tier is because Nims Middle School was left at its current 9:00 AM bell-time. This put the school 30 minutes from both tiers, and reduced pressure on the other High/Middle schools by occupying the deadhead capacity left over from the first PM tier. The effects of this "1.5 tier" can be more clearly seen in the AM distribution containing the three peaks.

Section VII – Conclusions

After preparation of the data, the Run Optimization study produced 406 bus runs and 68 van runs to service the students included in this study. A subsequent route coupling using standard parameters (including no route mirroring) yielded a total of 71 regular bus routes. If full route-mirroring was employed, then the total number of bus routes increased by 20 to 91 buses.

The Bell-Time Scenario utilizing the district-recommended approach generated 126 bus routes, while an Edulog-designed approach to the 2-tier system generated a more modest 91 bus routes. Neither scenario delivers a *savings* on the number of buses needed to serve the current transportation model if optimized, however, *the Edulog approach represents no net changes compared to the mirrored optimized solution of the current model*.

Route and Bell-Time Opt					
Results	**Buses**	**Vans**	**Total Routes**	Total Δ vs Current Routes	Bus Δ vs Current Bus
Current	107		107	-	-
Route Opt - No Mirroring	71	21	92	-15	-36
Route Opt - Yes Mirroring	91	21	112	+5	-16
Scenario 01 - District Approach	**126**	21	147	+40	+19
Scenario 02 - Edulog Approach	**91**	21	112	+5	-16

Results presented here are not road-ready for implementation. The analysis was based on data pulled from the Edulog system on February 18th, 2019 and is not reflective of changes made by the district since then.

During the route optimization process, the impact of having long arrival/departure windows becomes apparent. Both the AM and PM windows are at/around 30 minutes across all schools, which allow buses a high level of flexibility when making school stops. Due to Leon's urban-suburban topography, close to 20% of the optimized runs have a loaded run length less than 15 minutes. While this does not account for the needed deadhead distance required to connect two runs, it did result in a number of schools being serviced by double runs. If a district wishes to able to enforce a policy of long arrival/departure windows, then it can be an effective strategy of bussing students to school with limited resources. Any desire to the contrary would require the district to re-consider shorter bell-time windows within their Edulog data.

Another subject that was explored on the route-level was the use of route-mirroring in the generated solutions. If the district was to enact a policy of assigning both the AM and PM runs to the same route, then it inevitably leads to a less efficient solution and increased transportation requirements. While there are operational benefits to this policy, the various opportunity costs must be carefully considered.

Appendix A – Figures and Charts

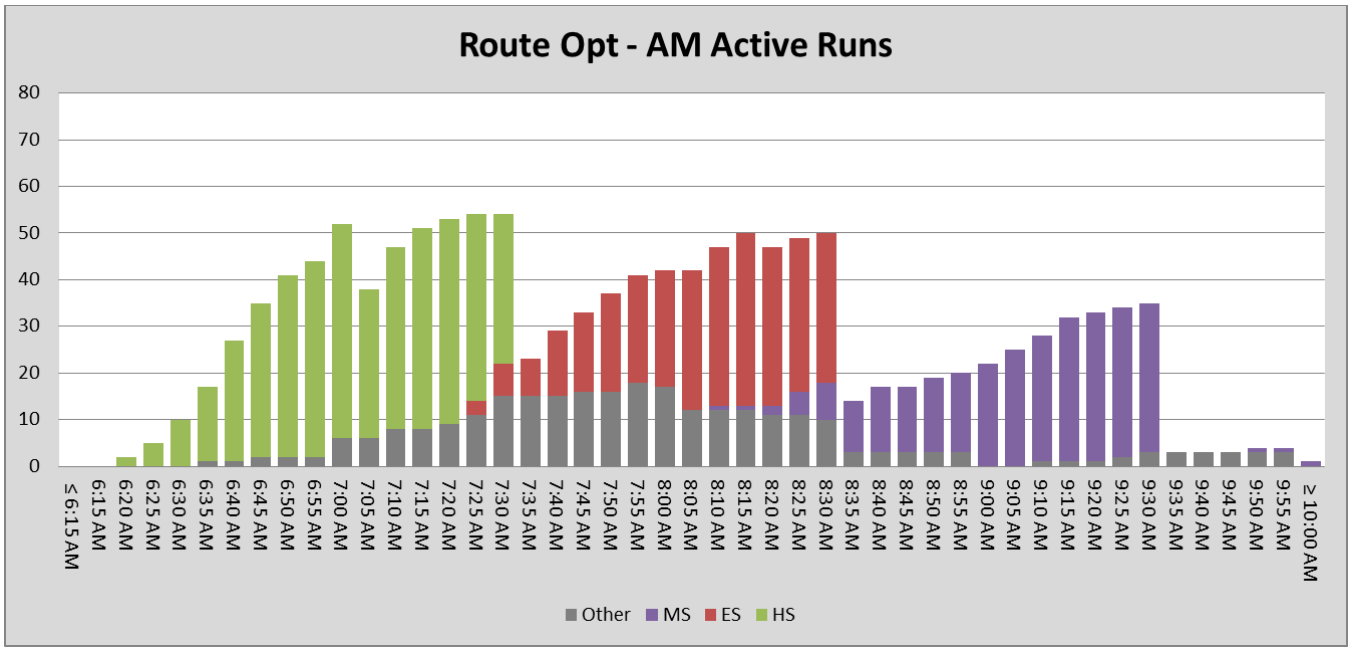


Figure A.1 – Active Run Counts for the AM period for the standard route optimizations (pre-Bell Time study), categorized by the type of school each runs services. Tallies are separated out into 5-minute bins to reduce noise in the data. Bell-Times for each tier of runs are generally- 7:30, 8:30, and 9:30 AM.

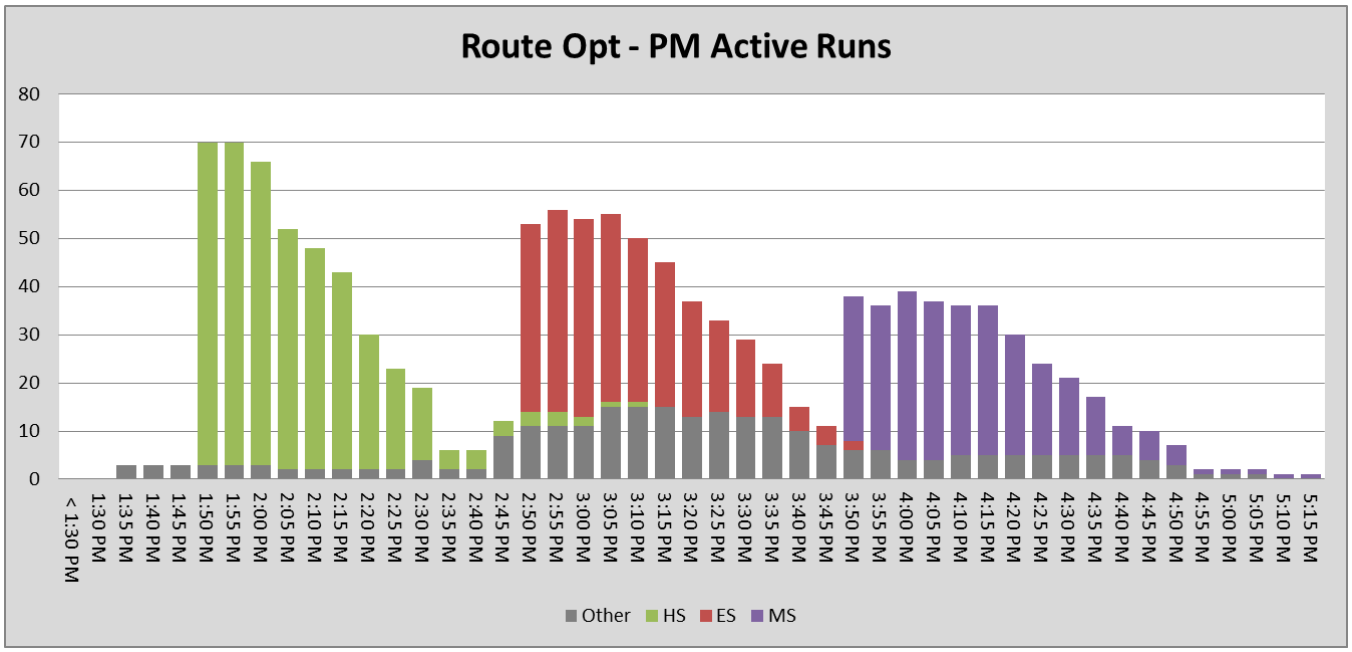


Figure A.2 – Active Run Counts for the PM period for the standard route optimizations (pre-Bell Time study), categorized by the type of school each runs services. Tallies are separated out into 5-minute bins to reduce noise in the data. Bell-Times for each tier of runs are generally- 1:50, 2:50, and 3:50 PM.

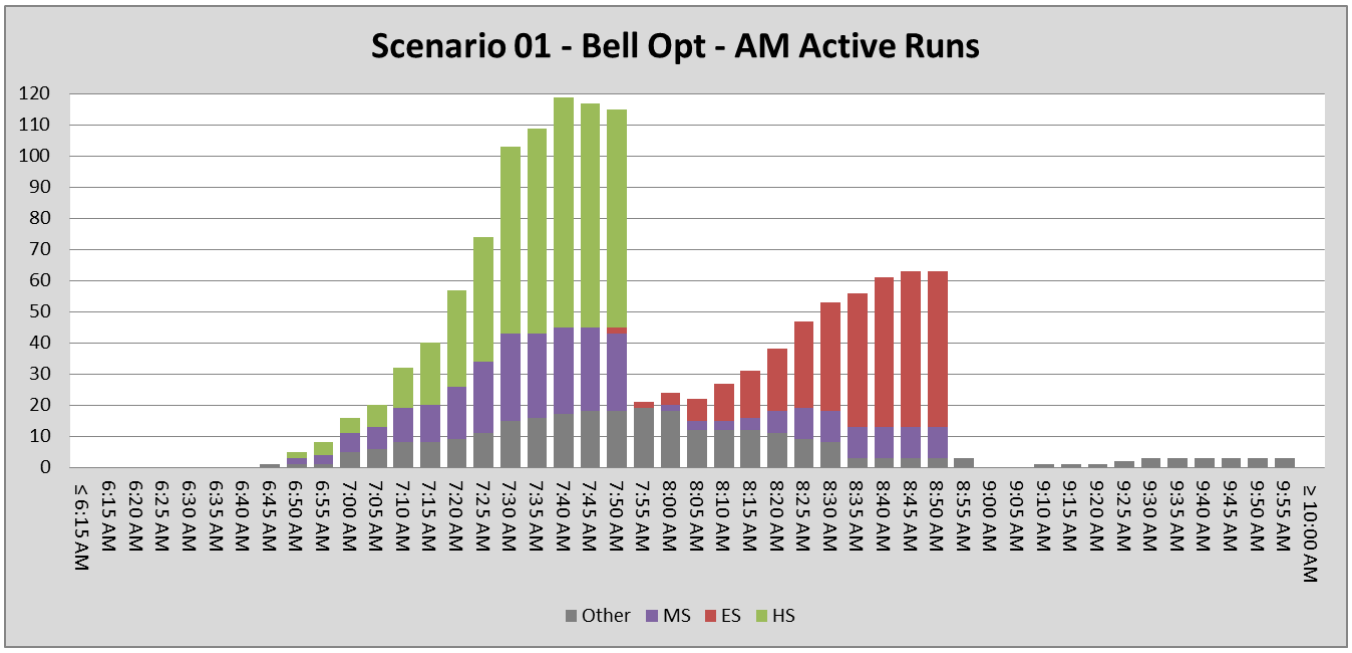


Figure A.3 – Active Run Counts for the AM period for the Scenario 01 of the Bell-Time Study, categorized by the type of school each runs services. Tallies are separated out into 5-minute bins to reduce noise in the data. Bell-Times for each of the two tiers are generally- 7:50 and 8:50 AM. Notice how the Middle Schools contribute directly to the absolute maximum on the 1st tier of 120 active runs. Swapping the schools would likely still yield over 100 active runs during that period.

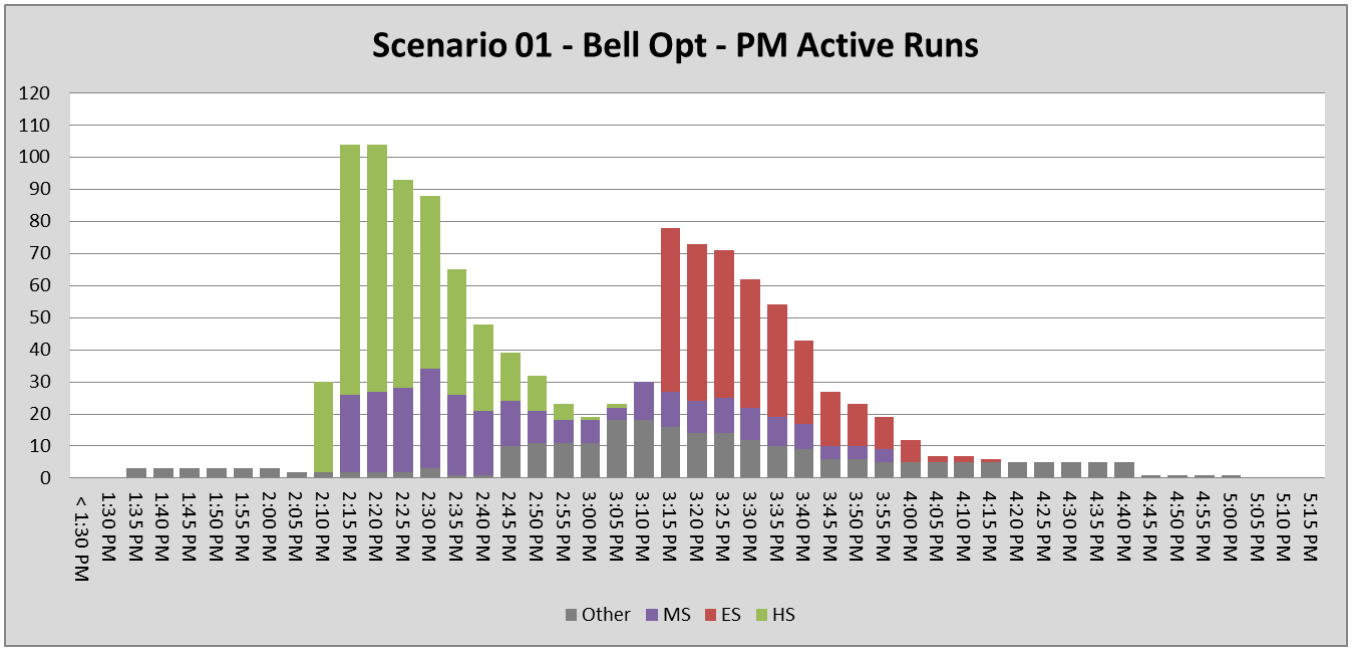


Figure A.4 – Active Run Counts for the AM period for Scenario 01 of the Bell-Time Study, categorized by the type of school each runs services. Tallies are separated out into 5-minute bins to reduce noise in the data. Bell times for each of the two tiers are generally- 2:10 and 3:10 PM. In this case both tiers are not the driving factor behind the 126 routes and they have enough space to accommodate all runs with no infeasibility.

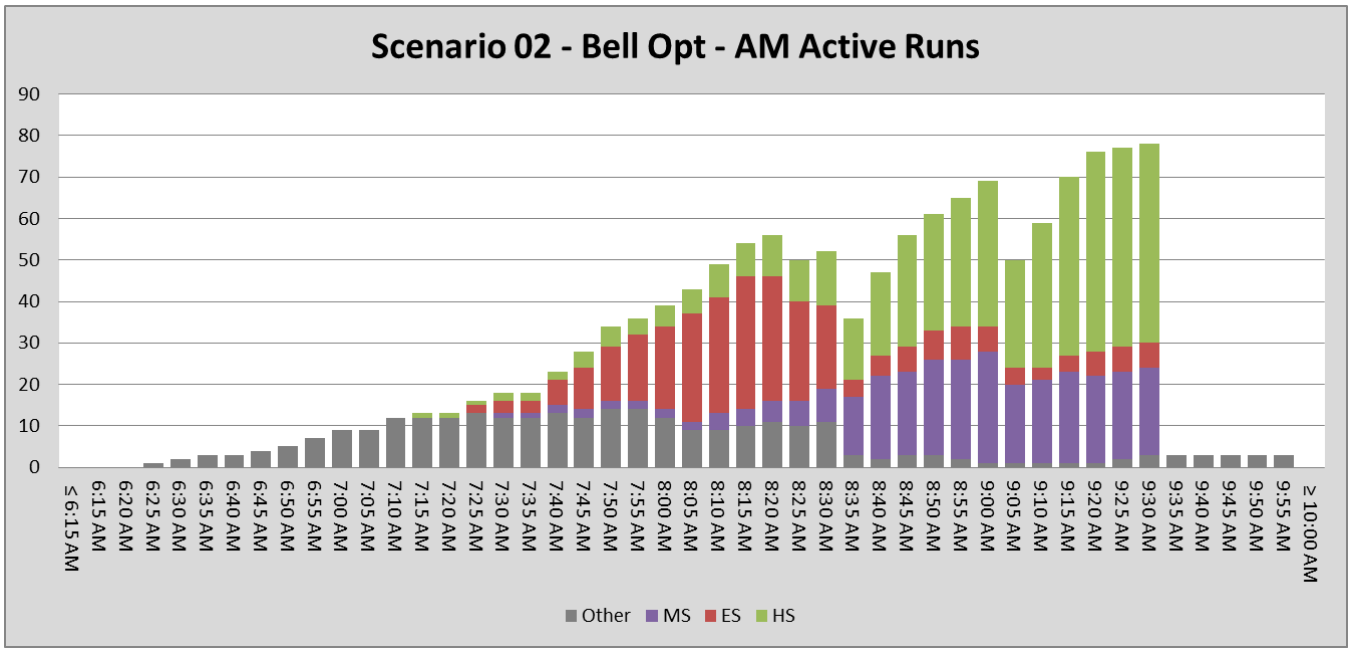


Figure A.5 – Active Run Counts for the AM period for the Scenario 01 of the Bell-Time Study, categorized by the type of school each runs services. Tallies are separated out into 5-minute bins to reduce noise in the data. Bell-Times for each of the two tiers are generally- 8:30 and 9:30 AM, with the notable exception of Nims Middle at 9:00 AM. The three peaks in the distribution reflect the alternative 2-tiered approach, and allows a more-even spread of runs across the morning.

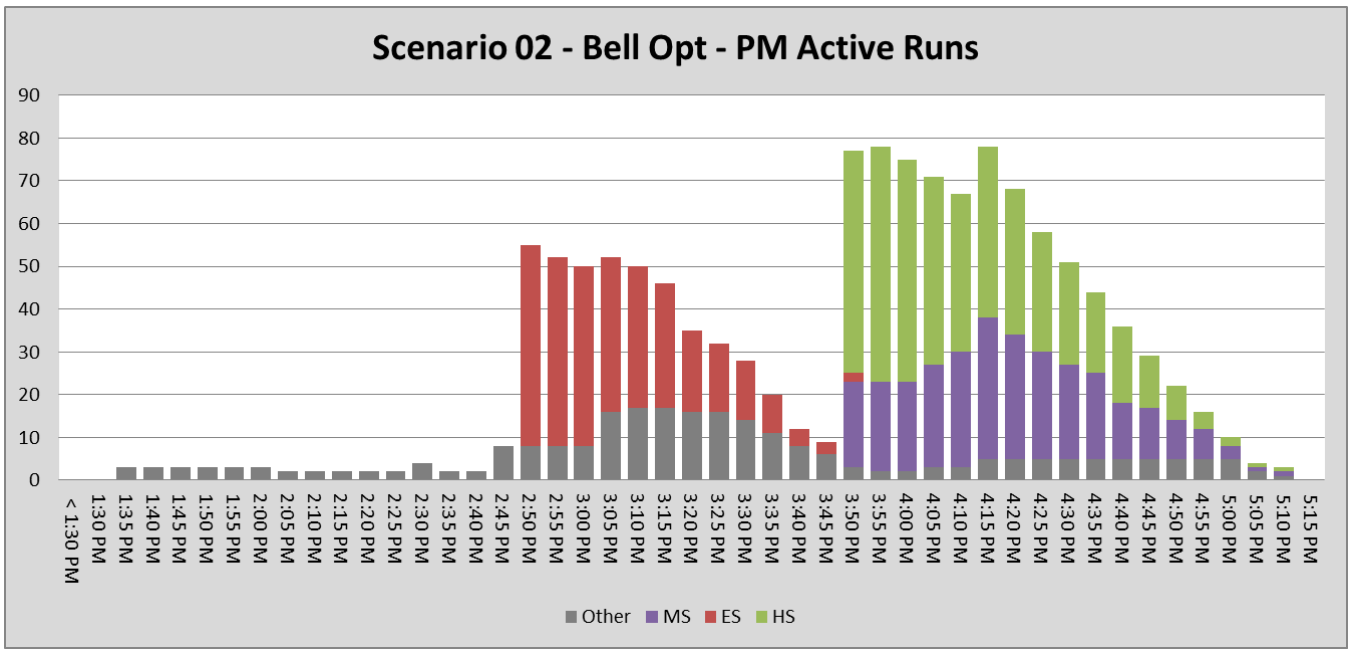


Figure A.6 – Active Run Counts for the AM period for Scenario 01 of the Bell-Time Study, categorized by the type of school each runs services. Tallies are separated out into 5-minute bins to reduce noise in the data. Bell times for each of the two tiers are generally- 2:50 and 3:50 PM, with the notable exception of Nims Middle at 3:10 PM. Notice how once again the afternoon tiers are not the constraining factor, accommodating all runs with ease.

Appendix B – Bell Time Shifts for each Scenario

		Current Times		Bell-Time Scenario 01		
Code	School Name	AM Bell	PM Bell	AM Bell	PM Bell	Tiers
0021	LEON HIGH	7:30 AM	1:50 PM	7:50 AM	2:10 PM	tier 1
0051	RICKARDS HIGH	7:30 AM	1:50 PM	7:50 AM	2:10 PM	tier 1
0161	GODBY HIGH	7:25 AM	1:50 PM	7:50 AM	2:10 PM	tier 1
1091	LINCOLN HIGH	7:30 AM	2:00 PM	7:50 AM	2:10 PM	tier 1
1141	LAWTON CHILES HIGH	7:30 AM	1:50 PM	7:50 AM	2:10 PM	tier 1
0222	GRIFFIN MIDDLE	9:30 AM	3:50 PM	7:50 AM	2:10 PM	tier 1
0451	FAIRVIEW MIDDLE	9:30 AM	3:50 PM	7:50 AM	2:10 PM	tier 1
0531	DEERLAKE MIDDLE	9:30 AM	3:50 PM	7:50 AM	2:10 PM	tier 1
1151	SWIFT CREEK MIDDLE	9:30 AM	3:50 PM	7:50 AM	2:10 PM	tier 1
1201	WILLIAM J MONTFORD MIDDLE	9:30 AM	3:50 PM	7:50 AM	2:10 PM	tier 1
0092	RAA MIDDLE	9:30 AM	3:50 PM	8:50 AM	3:10 PM	tier 1
1171	ROBERTS ELEMENTARY	8:30 AM	2:50 PM	8:50 AM	3:10 PM	tier 2
1202	J MICHAEL CONLEY ELEMENTARY	8:30 AM	2:50 PM	8:50 AM	3:10 PM	tier 2
0032	COBB MIDDLE	9:30 AM	3:50 PM	8:50 AM	3:10 PM	tier 2
0291	NIMS MIDDLE	9:00 AM	3:50 PM	8:50 AM	3:10 PM	tier 2
0031	SULLIVAN ELEMENTARY	8:30 AM	2:50 PM	8:50 AM	3:10 PM	tier 2
0041	HARTSFIELD ELEMENTARY	8:15 AM	2:50 PM	8:50 AM	3:10 PM	tier 2
0071	SABAL PALM ELEMENTARY	8:15 AM	2:50 PM	8:50 AM	3:10 PM	tier 2
0091	RUEDIGER ELEMENTARY	8:30 AM	2:50 PM	8:50 AM	3:10 PM	tier 2
0131	WOODVILLE ELEMENTARY	8:30 AM	2:50 PM	8:50 AM	3:10 PM	tier 2
0171	OAK RIDGE ELEMENTARY	8:15 AM	2:50 PM	8:50 AM	3:10 PM	tier 2
0231	RILEY ELEMENTARY	8:30 AM	2:50 PM	8:50 AM	3:10 PM	tier 2
0311	PINEVIEW ELEMENTARY	8:30 AM	2:50 PM	8:50 AM	3:10 PM	tier 2
0381	GILCHRIST ELEMENTARY	8:30 AM	2:50 PM	8:50 AM	3:10 PM	tier 2
0401	ASTORIA PARK ELEMENTARY	8:30 AM	2:50 PM	8:50 AM	3:10 PM	tier 2
0421	W.T. MOORE ELEMENTARY	8:30 AM	2:50 PM	8:50 AM	3:10 PM	tier 2
0431	SEALEY ELEMENTARY	8:30 AM	2:50 PM	8:50 AM	3:10 PM	tier 2
0441	APALACHEE ELEMENTARY	8:30 AM	2:50 PM	8:50 AM	3:10 PM	tier 2
0481	KILLEARN LAKES ELEMENTARY	8:30 AM	2:50 PM	8:50 AM	3:10 PM	tier 2
0491	CHAIRES ELEMENTARY	8:30 AM	2:50 PM	8:50 AM	3:10 PM	tier 2
0501	SPRINGWOOD ELEMENTARY	8:30 AM	2:50 PM	8:50 AM	3:10 PM	tier 2
0511	DESOTO TRAIL ELEMENTARY	8:30 AM	2:50 PM	8:50 AM	3:10 PM	tier 2
0521	BUCK LAKE ELEMENTARY	8:30 AM	2:50 PM	8:50 AM	3:10 PM	tier 2
0561	FT BRADEN ELEMENTARY	8:30 AM	2:50 PM	8:50 AM	3:10 PM	tier 2
1131	HAWKS RISE ELEMENTARY	8:30 AM	2:50 PM	8:50 AM	3:10 PM	tier 2
1161	CANOPY OAKS ELEMENTARY	8:30 AM	2:50 PM	8:50 AM	3:10 PM	tier 2
1181	BOND ELEMENTARY	8:15 AM	2:50 PM	8:50 AM	3:10 PM	tier 2
0191	SECOND CHANCE/ GHAZVINI LEARNING CTR	7:30 AM	1:30 PM	no change	no change	no change
0204	SAIL	8:00 AM	2:45 PM	no change	no change	no change
0411	GRETCHEN EVERHART SCHOOL	9:00 AM	3:00 PM	no change	no change	no change
0452	HERITAGE TRAILS	9:00 AM	3:00 PM	no change	no change	no change
1211	SUCCESS ACADEMY	8:30 AM	3:50 PM	no change	no change	no change
1441	GOVERNOR'S CHARTER	8:00 AM	3:00 PM	no change	no change	no change
9006	PRE-K	8:30 AM	2:30 PM	no change	no change	no change

		Current Times		Bell-Time Scenario 02		
Code	School Name	AM Bell	PM Bell	AM Bell	PM Bell	Tiers
0021	LEON HIGH	7:30 AM	1:50 PM	9:30 AM	3:50 PM	tier 2
0051	RICKARDS HIGH	7:30 AM	1:50 PM	9:30 AM	3:50 PM	tier 2
0161	GODBY HIGH	7:25 AM	1:50 PM	9:30 AM	3:50 PM	tier 2
1091	LINCOLN HIGH	7:30 AM	2:00 PM	9:30 AM	3:50 PM	tier 2
1141	LAWTON CHILES HIGH	7:30 AM	1:50 PM	9:30 AM	3:50 PM	tier 2
0222	GRIFFIN MIDDLE	9:30 AM	3:50 PM	9:30 AM	3:50 PM	tier 2
0451	FAIRVIEW MIDDLE	9:30 AM	3:50 PM	9:30 AM	3:50 PM	tier 2
0531	DEERLAKE MIDDLE	9:30 AM	3:50 PM	9:30 AM	3:50 PM	tier 2
1151	SWIFT CREEK MIDDLE	9:30 AM	3:50 PM	9:30 AM	3:50 PM	tier 2
1201	WILLIAM J MONTFORD MIDDLE	9:30 AM	3:50 PM	9:30 AM	3:50 PM	tier 2
0092	RAA MIDDLE	9:30 AM	3:50 PM	9:30 AM	3:50 PM	tier 2
1171	ROBERTS ELEMENTARY	8:30 AM	2:50 PM	8:30 AM	2:50 PM	tier 1
1202	J MICHAEL CONLEY ELEMENTARY	8:30 AM	2:50 PM	8:30 AM	2:50 PM	tier 1
0032	COBB MIDDLE	9:30 AM	3:50 PM	9:30 AM	3:50 PM	tier 2
0291	NIMS MIDDLE	9:00 AM	3:50 PM	9:00 AM	3:50 PM	no change
0031	SULLIVAN ELEMENTARY	8:30 AM	2:50 PM	8:30 AM	2:50 PM	tier 1
0041	HARTSFIELD ELEMENTARY	8:15 AM	2:50 PM	8:15 AM	2:50 PM	tier 1
0071	SABAL PALM ELEMENTARY	8:15 AM	2:50 PM	8:15 AM	2:50 PM	tier 1
0091	RUEDIGER ELEMENTARY	8:30 AM	2:50 PM	8:30 AM	2:50 PM	tier 1
0131	WOODVILLE ELEMENTARY	8:30 AM	2:50 PM	8:30 AM	2:50 PM	tier 1
0171	OAK RIDGE ELEMENTARY	8:15 AM	2:50 PM	8:15 AM	2:50 PM	tier 1
0231	RILEY ELEMENTARY	8:30 AM	2:50 PM	8:30 AM	2:50 PM	tier 1
0311	PINEVIEW ELEMENTARY	8:30 AM	2:50 PM	8:30 AM	2:50 PM	tier 1
0381	GILCHRIST ELEMENTARY	8:30 AM	2:50 PM	8:30 AM	2:50 PM	tier 1
0401	ASTORIA PARK ELEMENTARY	8:30 AM	2:50 PM	8:30 AM	2:50 PM	tier 1
0421	W.T. MOORE ELEMENTARY	8:30 AM	2:50 PM	8:30 AM	2:50 PM	tier 1
0431	SEALEY ELEMENTARY	8:30 AM	2:50 PM	8:30 AM	2:50 PM	tier 1
0441	APALACHEE ELEMENTARY	8:30 AM	2:50 PM	8:30 AM	2:50 PM	tier 1
0481	KILLEARN LAKES ELEMENTARY	8:30 AM	2:50 PM	8:30 AM	2:50 PM	tier 1
0491	CHAIRES ELEMENTARY	8:30 AM	2:50 PM	8:30 AM	2:50 PM	tier 1
0501	SPRINGWOOD ELEMENTARY	8:30 AM	2:50 PM	8:30 AM	2:50 PM	tier 1
0511	DESOTO TRAIL ELEMENTARY	8:30 AM	2:50 PM	8:30 AM	2:50 PM	tier 1
0521	BUCK LAKE ELEMENTARY	8:30 AM	2:50 PM	8:30 AM	2:50 PM	tier 1
0561	FT BRADEN ELEMENTARY	8:30 AM	2:50 PM	8:30 AM	2:50 PM	tier 1
1131	HAWKS RISE ELEMENTARY	8:30 AM	2:50 PM	8:30 AM	2:50 PM	tier 1
1161	CANOPY OAKS ELEMENTARY	8:30 AM	2:50 PM	8:30 AM	2:50 PM	tier 1
1181	BOND ELEMENTARY	8:15 AM	2:50 PM	8:15 AM	2:50 PM	tier 1
0191	SECOND CHANCE/ GHAZVINI LEARNING CTR	7:30 AM	1:30 PM	7:30 AM	1:30 PM	no change
0204	SAIL	8:00 AM	2:45 PM	8:00 AM	2:45 PM	no change
0411	GRETCHEN EVERHART SCHOOL	9:00 AM	3:00 PM	9:00 AM	3:00 PM	no change
0452	HERITAGE TRAILS	9:00 AM	3:00 PM	9:00 AM	3:00 PM	no change
1211	SUCCESS ACADEMY	8:30 AM	3:50 PM	8:30 AM	3:50 PM	no change
1441	GOVERNOR'S CHARTER	8:00 AM	3:00 PM	8:00 AM	3:00 PM	no change
9006	PRE-K	8:30 AM	2:30 PM	8:30 AM	2:30 PM	no change

Appendix C – Glossary of Terms

Assigned Load - The number of students assigned in Edulog to that service. Assigned load can refer to Stop Service or Run Service

Bell Time- The time the bell rings to signify the start or end of the school day

Bell Time Window- In the AM, this designates the earliest and latest time a bus can arrive at a school on a to-school run. In the PM, this designates the earliest and latest time a bus may leave the school

Load Time- The amount of time it takes for passengers and any equipment to board the bus

Route- The sum of the activity for an individual bus during a day, defined by a set of rns that a bus services during the day

Run- A run is a sequence of stops that a bus makes when transporting students to or from school. Identified by a Run ID number

Run ID- The school code plus a unique three-digit number that identifies a run for a school. For example, run ID 100.017 represents run number 017 servicing school 100

Stop- A distinct geographical location where buses stop during the day to pick up or drop-off students. A single stop can service multiple schools. Identified by a Stop ID number

Stop ID- The school code plus a unique three-digit number that identifies a stop for a specific school

Tier- A single or multiple bell time that, when grouped together, represent a single time frame grouping of runs. A typical transportation system has three tiers: Elementary, Middle, and High