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Automatic Generation of School Bus Routes in Los Angeles

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Issue

During the 2018–19 school year, the Los Angeles Unified School District (LAUSD) provided bus service to more than 37,000 students. Currently, LAUSD's routing team designs routes manually. The team must balance the cost and quality of service while adhering to several constraints, such as ride-time limits, bus capacities, and school-bell times. Of particular interest to LAUSD are the most efficient ways to handle "mixed-load routing," in which students from multiple schools are picked up along the same route. This practice is particularly beneficial when routes for different schools need to traverse similar paths. In this project, the researchers developed computer algorithms, a software implementation, and a user interface that automatically generates bus routes and allows users to edit them.

The researchers used the number of bus routes and the mean time that students spend riding to measure approximate cost and service quality, respectively. It is desirable for both the number of routes and mean ride time to be small, but there is a tradeoff between them: decreasing one usually comes at the cost of increasing the other. Although the problem size is far too large to find optimal solutions, it is feasible to use algorithms to produce route plans that can be compared to each other and to LAUSD's existing routes using number of routes and mean ride time.

Key Research Findings

- The researchers' computer algorithms generated route plans of similar quality to those that were designed by LAUSD staff. In some cases, the algorithms generated plans that were better than those from LAUSD.

- The researchers used several different algorithms to generate initial route plans and then applied post-processing procedures to improve those initial route plans. These procedures included reordering stops to decrease ride time, reassigning stops from one route to another, and splitting existing routes to incorporate them into others.

- It is better to design routes with multiple schools in mind than to design single-school routes, which must then be combined later.

- The researchers found it helpful to create initial route plans without considering capacities and then, for each route with too many students for a single bus, to break the route into multiple routes with fewer students, such that the new routes have sufficiently few students for the buses. Based on the researchers' tests, this approach tends to outperform approaches that consider buses earlier in the routing process.
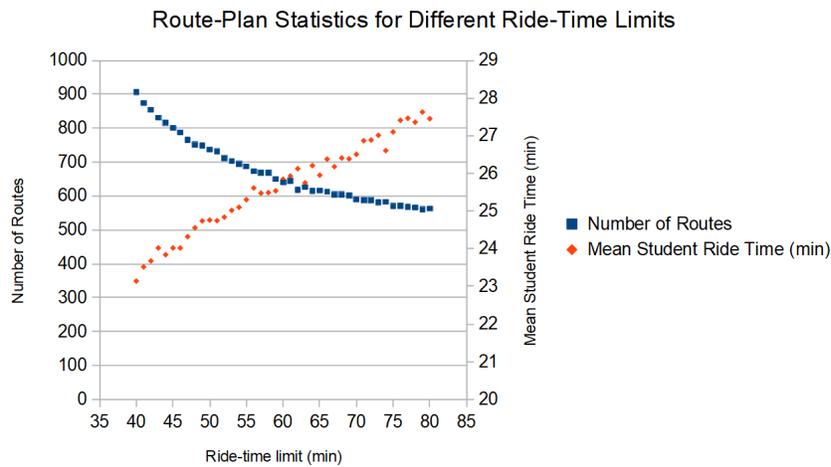
Figure 1. This plot shows the route-plan statistics for automatically generated routes for different maximum amounts of time that students are allowed to ride on buses.

Study Approach

The research team used LAUSD's data along with a mapping source as input for computer programs — both the implementation of existing algorithms and new approaches that they developed — to create routing plans. They employed algorithms based on several distinct ideas, the three most successful of which were route combining, school grouping, and bus-stop valuation. The team then compared the outputs, including the number of routes and the mean ride times, from each algorithm both to each other and to LAUSD's manually generated routes. The most successful algorithm placed values on bus-stop pickups. That algorithm keeps adding pickups based on a balance of pickup value and pickup time until it cannot add more stops without violating the travel-time limit. The team also developed a user interface to allow non-technical members of a school district's routing team to generate, view, and edit routes.

Conclusions

- The most effective algorithm produced route plans with fewer buses, but a marginally higher mean ride time, than LAUSD's existing route plan.

- One benefit of automating the route-generation process is that it facilitates evaluation of the impact of proposed policy changes (such as changing the maximum ride time).

- The study found that widening the allowed drop-off time interval would not result in a significant reduction in the number of routes. Therefore, the researchers concluded that it would not be beneficial to adjust school drop-off times and ask schools to receive students earlier.

- The goal of the software is not to automate the route-generation process entirely, but instead to give school-district teams a good starting point of efficient routes for them to adjust with their knowledge and expertise to achieve a better balance between cost and quality of service.

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