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How One City Saved $5 Million by Routing School Buses with an Algorithm

School buses line up in Boston, a city with one of the most challenging systems to route.

SHUTTERSTOCK

By Emma Coleman | AUGUST 12, 2019

The Boston Public School District held a contest to determine the best solution for busing around 25,000 students to school every day. The winning algorithm improved the efficiency of the routes in 30 minutes.

EDUCATION BOSTON NEW TECHNOLOGY

The yellow school bus has remained largely unchanged since it first debuted in 1939. But while the buses look the same, their routes have grown infinitely more complex in the past 80 years, as the number of students, schools, and road systems grow and change.

Drawing bus routes for Boston Public Schools involves challenges unique to the city. BPS allows parents to select their child's school from a list of about ten options, in an effort to reduce inequalities that might result from isolating students to their neighborhoods. While this represents a greater level of choice than most cities, the resulting bus routes can be meandering and complicated.

Compounding that challenge is the fact that BPS provides more bus services than most other districts. All elementary school students who attend schools more than a mile from their home are offered yellow bus service to one of over 220 schools, and many live much farther than that. Some schools draw students from more than 20

In 2017, the district was facing serious challenges. On a per-pupil basis, BPS had the highest transportation costs in the country, around $2,000 per student per year, representing 10% of the district's budget. The schools dealt with rising costs each year, despite declining ridership. The on-time performance rate of their buses was also well below that of other large districts.

With no clear vendor to turn to with this problem, BPS instead sought out experts, hosting a competition where researchers could experiment with anonymized BPS data sets to create efficient routes and optimal start times for each school.

"To put it simply, we wanted a solution that worked," said Will Eger, the BPS senior strategic projects manager. "There are lots of quirks in this transportation situation, and we wanted something that could address the vast majority of those issues while also being highly efficient, something that could run overnight at least."

Those quirks represent millions of decision variables that affect any solution, including varying road widths, differing bus infrastructures (for example, the presence of wheelchair lifts or child safety restraint seats), students who require the same bus driver every year, students who have monitors, and students who have been in fights and, therefore, need to be on different buses. It also includes the roughly 5,000 students who have a special need that requires door-to-door pick up and drop off (sometimes to non-BPS schools, as the city provides yellow bus service to students who attend charter and private schools within Boston, and to special education facilities outside the city).

Considering all those possibilities creates a "number of solutions so large that you can't even enumerate it," said Arthur Delarue, a PhD candidate who worked with the team from the MIT Operations Research Center whose algorithm won the competition. The team spent hundreds of hours devising a solution to what Delarue called a "bold and unusual" challenge.

Their solution replaced what had before been an incredibly laborious process, one that took ten school system routers thousands of hours to create custom routes for each child and school. Those employees still work with BPS, tracking routes that struggle with on-time performance, and managing route guidance for drivers (Google Maps isn't sufficient since it's built for cars, and 70-passenger buses can't, for example, easily make u-turns). But now, the MIT algorithm routes the entire system at once, providing a base for the human routers to tweak.

"The work of route managers in communicating with stakeholders such as drivers, principals, parents, and students is invaluable and cannot be replaced," Delarue said. "But in what order stops should be visited, and how that route gets designed can't be solved efficiently by humans. That's where we add value."

Sebastien Martin, another PhD candidate at MIT who worked on the solution, said the dilemmas with drawing school bus routes have been studied since the 1960s, and many solutions have been proposed. "Each school district has such different needs, though, so it's hard to find a solution that works perfectly everywhere," he said. "The problem is so hard to solve that even the most powerful computers can't find a perfect solution for a district the size of Boston. There will always be tradeoffs."

efficient than the ones done by hand. The longer the algorithm runs, the better solution it produces, until it cannot be improved. Running the algorithm in the summer of 2017 allowed for the system to eliminate 50 buses, an 8% drop in the fleet that was the largest Boston had seen in a single year. Buses drove 1 million fewer miles that year and cut 20,000 pounds of carbon dioxide emissions per day. The district reinvested the $5 million saved back into classroom initiatives.

"Incredibly, this was done without making bus rides or walk time to stops longer," said Eger. "We now have shorter walk times for younger students and those in dangerous neighborhoods, and we still minimized the total number of stops."

Much of the algorithm's success is derived from the fact that it takes a system-level approach, instead independently routing individual schools and then connecting those routes together. Instead, the algorithm assigns students to stops, puts the stops in order to make no student's ride longer than an hour, and then takes a multi-school routing approach. The best solution, then, is not the one that uses the fewest number of buses for each school, but the one that most effectively recycles buses on paths to multiple schools—and the solution uses flexible integer programming that allows the district to adapt to changing policies.

Now in its third year of operation, Eger said that BPS runs the algorithm in the summer to create a master schedule, and then makes modifications by hand throughout the year, though they're trying to integrate the two systems so that changes can be done by the algorithm throughout the year. But the more powerful potential to come out of the challenge, in his opinion, was another algorithm, one that allows for "unprecedented insight" into the implications of policy changes, such as school start times.

"This was really eye opening for us," said Eger. "We can understand now the cost and equity effects, and number of students who might be impacted by any given policy changes."

But just because the district has been able to clearly enumerate the effects of policy changes doesn't mean they've been popular. In December 2017, based on the recommendations of the algorithm, the Boston School Committee approved changes in school start times for the first time in 30 years. Those changes would have involved 85% of schools.

The move was based on several considerations, including research that showed starting high school before 8 a.m. has detrimental effects on the learning ability of teenagers. MIT research also showed that Boston was inequitable—while most parents prefer start times between 8:00 and 8:30 a.m., only 10% of white students in Boston start before 8:00 a.m., compared to 30% of black students. Higher income students generally start later, at the more desirable times.

So the team worked to swap the start times of high schools with elementary schools in the district, and optimize the start times based on route feasibility, teen health, parent preferences, and equity. Their school start time algorithm explored the tradeoffs to different start times, and found a balance point between all considerations. If it had been deployed, it would have changed the number of teenagers with early high school start times from 74% to just 6%.

pointed out in a presentation about the solution, those who favored the status quo had the most to lose. “When your kids are affected negatively, it is hard to see the big picture,” he said.

MIT eventually partnered with the *Boston Globe* in 2018 to show how the time algorithm could alter the start times at individual schools, but sweeping changes have still not occurred. Even so, Eger said that the project has been inspiring for the district, and the city as a whole.

“This is a positive example to show how we can use some of the unbelievable research potential that Boston has the offer,” he said. “Many school districts have operational problems like this, and handling these complex challenges is not our line of expertise. We should rely on experts for that, and focus on the work we do best.”

Emma Coleman is the assistant editor for *Route Fifty.*

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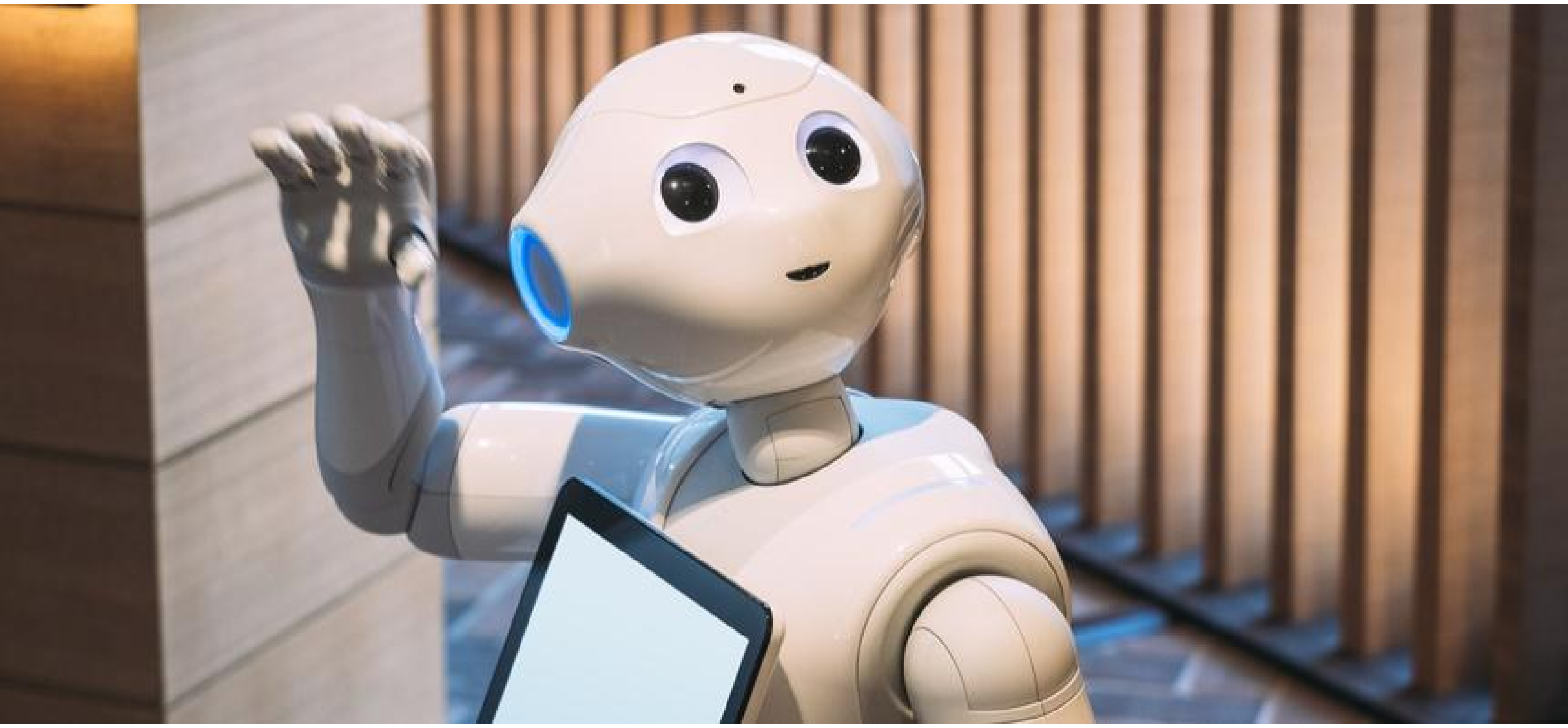

Roanoke County Public Library was the first in the country to acquire Pepper, which had been primarily used in retail and business environments. SHUTTERSTOCK

By Kate Elizabeth Queram | AUGUST 7, 2019

A humanoid robot named Pepper helps teach coding at Roanoke County Public Libraries, one of many branches across the country embracing the emerging technology.

ROBOTICS PUBLIC-PRIVATE PARTNERSHIP COUNTY GOVERNMENT

In Roanoke County, Virginia, a trip to the public library might include reading, online research, 3D printing—and, since last summer, the opportunity to chat with Pepper, a 4-foot-tall humanoid robot who sings, dances and teaches coding classes.

The Roanoke County Public Library was the first public system in the country to acquire Pepper, a decision made by staff members during a strategic planning session that focused largely on how the library hoped to evolve in a modern world increasingly focused on technology. During that discussion, someone mentioned that they'd heard


"Tell a story"
"Do something fun"
"Need information"

The robot, manufactured by SoftBank Robotics, had been primarily deployed as a greeter and receptionist in hotels, stores and banks, although a K-12 educational model was also available through RobotLAB, a separate company. Developers there had been interested in working with a library, Henry said, and after a video call with the CEO, the two groups decided to work together.

Pepper was purchased by the local nonprofit Friends of Roanoke County Public Library after Henry and several staff members gave a presentation explaining how the robot could help the library accomplish its long-term goals. Those included making advanced technology accessible to everyone, and continuing to educate consumers about data privacy and storage.

“We said, ‘We can’t promise you that this isn’t risky. It’s bleeding-edge technology, and we acknowledge that,’” she said. “We tried to answer all of their questions. I think the final thought was that it would be cool, especially for children and for special-needs children in particular.”

robot's repertoire expanded quickly to include STEM presentations and coding classes. These give groups—from children to retirees—the opportunity to program Pepper to perform certain tasks, such as reading a story or participating in chair yoga.

"The classes pull up Choregraphe, a computer language that's proprietary to Pepper," Henry said. "And they decide what they're going to have Pepper do. It's a tangible outcome, they see it happen. There's something that Pepper brings out in you that just feels very powerful, and for the rest of their lives these groups can say they were part of coding this robot to do X for the community."

Courtesy of the Roanoke County Public Library

Henry envisions even more uses for Pepper in the future, including more educational programs and making the robot part of curriculum to broach sensitive topics like drugs and suicide with teenagers. The technology may seem advanced for a library, but branches across the country are embracing artificial intelligence as a community tool, ensuring access and educational opportunities for patrons who may not otherwise have the chance to experience it. Those measures range from interactive art installations to augmented reality displays to initiative for its members earlier this year. “As the AI revolution transforms every aspect of our lives, libraries are stepping up to ensure they can continue to fulfill their essential role as anchor institutions and lead their communities forward.”

Achieving that goal is not without risk, Henry noted. For example, earlier this year Roanoke’s library system deployed a series of tiny robots at multiple branches, only to see the parent company go out of business, leaving the future of the devices somewhat in doubt (for now, the company is still providing support for existing machines). But utilizing Pepper generated excitement within the community, garnered publicity for the library and inspired staff members to aim bigger in their goals—outcomes that more than justify the potential hazards, she said.

“It’s worth the risk because libraries are about innovation. So it's okay if it's hard and if sometimes things do not go according to plans,” she said. “It’s made us drive a little higher, and that’s been great for us and for what we do.”

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