Intelligent Transportation Systems & The Education Sector

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[http://s3-us-west-2.amazonaws.com/teague-new-development/uploads/photography/School-Line-Up.jpg]

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Introduction

Recent decades have seen tremendous advances in the world of Intelligent Transportation Systems, ranging from Autonomous Vehicles (AVs), smart sensors in and around roads and vehicles, and smart traffic lights (Blazina, 2017) just to name a few. However, despite the advances that may be happening at large, the education industry is one that is not benefiting much from them. While commercial vehicles and trucks see delays for five years relative to consumer vehicles when it comes to new technologies, school buses can experience 5-10 years of additional lag (Andersky, 2017). This creates an environment where, due to a variety of historic reasons that this paper will briefly overview, school buses are predominantly not benefiting from the advances being seen in other automotive areas.

School transportation in the US still heavily relies on the iconic yellow school buses, of which roughly a third are contracted out and not owned by the districts themselves (Schiess, 2017). There are roughly 500,000 buses that transport 25 million students annually and in 2017 there are over 50 million students attending public and secondary schools in the US (National Center for Education Statistics, 2017). Though total ridership is increasing in the United States, the percentage of students using school buses is decreasing (Schiess, 2017). There are a variety of reasons that have led to the challenges currently being faced that will be explored here, but the end result is a fleet of hundreds of thousands of schools buses that do not have the basic technology to become fully optimized for safety and efficiency. That is why we are focusing on suggestions in the short-term (1 - 10-year range) and the long-term (10+ years) as there first needs to be a wave of 'smartification' before there can be a more serious focus on autonomous vehicles. Before exploring these ideas further, we will examine a brief overview of the history of education and related transportation.

History

When education first started in what would become the United States, it was mostly provided through churches and focused on religious education (The American Board, 2015). By the mid-1600's some public education started being provided, with the Boston Latin School being the first to open its doors. Massachusetts was one of the first places to pass a law on mandatory education as early 1647 during its days as a British colony and then another such law in 1852, which was the first compulsory education law in the United States (Find Law , 2017). The 18th Century saw the emergence of one-room or Common Schools as they're frequently known, which were open to students of all ages (The American Board, 2015).

This time marked an era of change in education overall, when education went purely from being a means of religious study to becoming a way to prepare for work and basic labor. When the U.S. Constitution was written, it made no mention of education. It was only in the 10th Amendment that assigned the responsibility of education to states. 1823 was when 2-year normal or teaching schools started to advance and slowly helped shift the background of teachers away from individuals waiting to get married or finding a different role to being an actual career. Nonetheless, it took until after World War II for teachers to be required to have a 4-year degree. Despite the lack of a more supportive structure, all of the states had free elementary schools by 1870 and the U.S. population had some of the highest literacy rates in the world. From 1880-1924 there was an explosive growth in high school student population with the arrival of millions of immigrants from Europe, which saw a growth from less than 7% of kids ages 14-17 being in school in 1880 to 30% in 1924. Vocational training was also growing very strongly at this time (Singer, 2016).

IMAGE 1

[https://c1.staticflickr.com/1/348/20317682368_b9b5b5c625_b.jpg]

By the 1910's and 1920's, the horse drawn "school hacks" or "kid hacks" (IMAGE 1) as they were known started being swapped for engine based buses. The 1930's saw the first standardization school related vehicles and in 1939, Dr. Frank Cyr organized a conference funded by the Rockefeller Foundation on school buses that helped spur a national discussion. This meeting resulted in 44 standards, including the yellow color that we all know today (School Transportation News, 2007). The following decades, especially after World War II, saw high growth in the number of students due to the population growth undergone in the United States at the time (National Center for Education Statistics, 2017).

However, transportation in the context of the school system in the United States is something that has not deeply changed in decades since the last major push for regulation around school buses in the 1960's and 1970's, which included the National Traffic and Motor Vehicle Safety Act (NTMVSA) of 1966, the formation of the National Association of State Directors of Pupil Transportation Services in 1968, and The Motor Vehicle and School Bus Safety Amendments of 1974 which allocated over $100m to actualizing some of the initial NTMVSA proposals. These two decades saw extensive focus on the safety of buses and a further standardization of the features on the buses themselves (School Bus Fleet , 2006).

In the 1970's, the term "busing" became synonymous "with court-ordered desegregation of schools in cities across the country. Changes in student transportation may facilitate (or hinder) changes in schooling options, thereby changing the quality and character of education that a student is able to receive" (Urban Institute Student Transportation Working Group, 2017). The decades since then have seen shifts in terms of more students switching to charter schools, more students generally attending school due to a rise in a population, and yet a decline in the percent of students who use school buses (Schiess, 2017). This shows that the role that transportation is currently playing in American society runs much deeper than simply a way of getting kids to school. This is directly linked to the political complexity of educational and social policy that are inextricably linked with school run transportation, though this paper will not explore these social questions and will purely focus on the technological and related components.

Aside from a rise in the electrification of school buses in the 2010's, there have been no major changes when it comes to the school buses themselves. The one exception to this is that aside from diesel and gasoline, more school buses have started switching to propane for cost reasons (American School Bus Council, 2017). This signifies one of the overall issues, that many buses have not seen any major advancements while many other forms of transportation have reaped benefits from technological breakthroughs of recent decades. Though some technological components such as cameras and GPS are making their way into buses, the penetration is much lower relative to other modes of transportation (McMahon, Equipment Survey, 2015).

Current State of Transportation in Education

Today, schools employ over 515,000 school bus drivers (Occupational Employment and Wages, 2017) and there are a total of 480,000 school buses that transport 26 million students daily (National School Transporation Association, 2013). Most school buses have not gone through any major technological changes beyond having video cameras, and that's only in roughly 50% of existing buses (McMahon, Equipment Survey, 2015). The average age of a school bus in the U.S. is 9.3 years as of 2016 (Morse, Malgrem, Wallace-Brodeur, & Whitaker, 2016), though some school districts deal with buses that can be 30 years old (Simkovic, 2016). The challenges around funding have forced the pay for bus drivers to progressively go down, and in turn has led to a shortage of drivers (Weller, 2017).

We are going to explore the current state of education as it relates to student safety, the cost and funding challenges around school transportation, the ownership of buses, the declining ridership, the lack of data, and the environmental concerns related to school buses.

Student Safety

Student safety has always been a top concern, and naturally so given that parents are entrusting their children to strangers in the process of getting them to school. From 2000 to 2009, 0.34% (1,245 out of 371,104) of the total fatal motor vehicle traffic crashes were classified as school transportation related. During that time 130 students were killed, of which two-thirds were struck by school buses, 6% by other vehicles functioning as school buses, and the remaining 27% by other vehicles (National Highway Traffic Safety Administration , 2011).

On average, 134 people die in school-vehicle related crashes annually. “Once a bus begins rolling down the road, a child is, statistically speaking, safer inside the bus than outside it: Of the 327 school-age children killed in school-transportation-related crashes since 2004, 54 were children riding in buses. Accidents involving these vehicles, NHTSA found, are almost three times as deadly for occupants of the other vehicles” (Toppo, 2015). Durham School Services, which transports than 1 million students daily (Durham School Services, 2017), has had 346 crashes over two years resulting in three crashes with deaths and 142 with injuries over a two year period (Associated Press, 2016).

These examples highlight some of the issues that are faced due to a lack of technology in buses. There are many basic hardware upgrades that could assist drivers, such as: blind spot detection, lane departure warning, electronic stability control/full stability systems, radar-based collision mitigation, camera and radar-based collision mitigation, data from these and similar systems, and air disc brakes (Andersky, 2017). By focusing on a tech-first approach in terms of improving the school buses, then we can start taking some basic steps towards ensuring that less buses hit students and get involved in accidents overall, in addition to adding operational benefits.

Ownership of Buses

There are three primary service models in terms of school buses[1]: district-provided school buses, contracted school buses, and public transportation. In terms of school buses, district-owned ones constitute roughly two-thirds while contracted ones make up the other third. The district-run model entails the schools fully controlling and executing transportation services, which they provide for students living a certain distance from the school or in need of special assistance. In the contracted model, the contractor is the one that handles the purchasing of new buses, maintaining the fleets, and human capital management. The public transportation model is not frequently used and when it is, it’s mainly in urban centers.

[1] Unless otherwise stated, school bus and yellow bus are both referring to the same type of bus that transports students to school and is painting the legally required yellow color. We will generally be referring to the 72-passenger Type C buses.

Part of the challenge with the current structure is that it is so fractured that it has become tough for schools and districts to coordinate. This problem has both technological and bureaucratic components – given how behind many school bus fleet organizations are in terms of the technological state of buses, it's not surprising that schools and districts lack the ability to work across geographies. Especially when it comes to urban contexts, it's so important to consider the relationship that school transpiration has with public transportation as a whole in those areas. In order for traffic to be running as smoothly as possible, there would need to be more data sharing, which is currently a challenge for buses. This question becomes heightened when thinking of autonomous buses and vehicles and in general.

Access to opportunities in the form of the best schools is another problem that is exacerbated due to the current funding and school-type layout. Denver attempted to deal with this situation by offering free public transportation for students. A new study from the Center on Reinventing Public Education in Washington State shows that even if Denver does provide student free access to public transportation, it would not give equal access to all. Given the city's size and geography, only 58% of students would be able to get one of the top middle or high schools in under 30 minutes or less (Asmar, 2017). Therefore, it's important to consider new types of last mile solutions that can include private ride-sharing companies to help cover such gaps.

Cost and Funding Challenges

The complex background of education in the United States has resulted in an inconsistent landscape with no clear best practices. It also created an environment where it is tough to easily identify a single source of funding for new project across districts and states, especially given the massive scope of required change. As of now public school transportation costs approximately $500 per year per pupil. Only Pennsylvania transports all school children at state expense. The total expenditures for education related transportation according to the Department of Education's data was $24,164,005,000 in 2012-2013 (National Center for Education Statistics, 2017). Due to the financial constraints alongside a steady decline in ridership, there has been a 75%+ increase in the cost per student transported. As a result, there are approximately 250,000 school buses in the US which were manufactured before 2007, when more stringent emissions regulation went into effect (Schiess, 2017).

As of today, there are three basic models for state strategies in terms of funding school related transportation:

- Cost-based reimbursement
    - States reimburse for a portion of costs or based on a formula of expected expenses
- Per capita reimbursement
    - States reimburse districts with a set amount per student
- Linear density or mileage-based reimbursement
    - States reimburse base on the miles travels, either by the bus or the average miles traveled by student (linear density) (Schiess, 2017)

State transportation funding rarely covers the full cost of transporting students. "The diminishing state share of school transportation funds creates a natural incentive for school districts to seek cost efficiencies. But districts' ability to be efficient is limited by state and federal laws and regulations requiring bus service, establishing student eligibility for service, and limiting vehicle choices" (Schiess, 2017). This creates a very challenging situation where schools are hamstrung both by limited budgets as well as structural inefficiencies. This has led more schools and districts to consider contracting as an ever more appealing option. For districts that are currently dealing with major inefficiencies, shifting to contracting can have immediate positive impacts financially speaking (TransPar Group, 2013). There have been attempts in terms of passing legislation to help deal with the rising cost of student transportation (110th Congress, 2008), however, they aren't getting much traction.

These challenges around funding have forced the pay for bus drivers to progressively go down, and in turn has led to a shortage of drivers (Weller, 2017). In terms of bus driver pay, the situation has gotten as bad as the average school bus driver earning about $14.70 per hour, less than other transit drivers, who earn at least $19.31 on average depending on the type of vehicles they are driving. This has led to an intense bus driver shortage that many school districts experience (Schiess, 2017). In School Bus Fleet's Top 50 Contractors survey, 54% report a moderate shortage while 22% and 5% report severe and desperate shortages, respectively. Given the consistent shortages, fleets have turned to offering signing and/or referral bonuses, increasing pay or benefits, offering paid training, and generally increasing advertising spend. This in turn has brought up school bus driver compensation somewhat to an average of $16.90 in 2017 in certain markets (Schlosser, Contractors Boost Incentives, Advertising to Attract Drivers, 2017), though still below the levels drivers in other transportation areas get paid (Schiess, 2017).

Though districts may turn to contracting as an attempt to reduce costs, these cost savings from contracting are not a given. Here in Pennsylvania, districts end up paying more when contracting out. On average, districts saw their costs increased by almost $225,000 after contracting out relative to the districts owning their own equipment. Still, the state offered incentives to contract so just over 70% of the state's school transportation was contracted out in the 2008 school year (Keystone Research Center, 2012). On the other end of the spectrum, South Carolina is an example where the state created incentives to not contract out, despite the fact that many districts are dealing with an ever older fleet. There, they have seen a variety of districts which have buses ranging from 20-30 years old (Simkovic, 2016). This is especially problematic when considering the amount of rides that are over 90 minutes in a single direction, which in South Carolina is roughly 1,776 routes out of 18,062 (Self, 2015).

Another strategy to cut costs is with a more revenue focused approach in the form of charging parents for transportation of students, an activity that certain states condone while others outlaw (Schiess, 2017). Areas that do charge have created fees ranging from $180 to $575 per student per year, with certain caps in place for families with multiple students (Bergal, 2015). A less-common revenue-side strategy relates to compensating parents who choose to opt out of school bus transportation. In Ohio, where this type of strategy was trialed, payments to families opting out ranged from $250 to a maximum of $925.08 (Ohio Department of Education, 2016). Some urban centers are getting rid of school buses altogether and are focusing on public transportation. "For example, the District of Columbia has relied on public transit for decades, offering subsidized fares since 1978, just two years after the first lines of the region's subway system opened" (Authority, 2015).

In addition to all of these challenges and approaches, school districts also have to deal with a variety of policies that can present challenges when coming up with alternative solutions. "Through the U.S. Department of Transportation's Federal Transit Administration (FTA), which regulates public transit systems, the federal government imposes regulations preventing public transit providers from competing against private school bus operators." This creates a challenging environment where it becomes tough for schools to partner with the local public transport providers to think of potential alternatives. Those areas that do rely on public transport only do so for older students (Schiess, 2017). It also makes it challenging for the schools to think of potential alternatives for individual students who may live very out of the way relative to their peers, in turn adding significant commute time for all of the other students on the bus (Weller, 2017).

Declining Ridership

In terms of student ridership, the actual percentage of students has been falling from 60.7% of students in 1988 to 54.6% in 2007 while the number of students grew by almost 3 million over the same time. This paradigm of an increase in overall quantity of students but a decrease in the percentage of students has led towards an ever increasing cost per student (National Center for Education Statistics, 2017). As these costs continue to rise, they add to the aforementioned funding challenges that only exacerbate the circumstances that lead to less students riding school buses.

We are also in an environment where less students have been walking or riding bicycles to school as well. In 1969, roughly half of students in the U.S. walked or rode their bikes to school, which has dropped to less than 15% as of 2011 (Safe Routes to School National Partnership, 2011). If students are being transported to school, then it should be a top priority to ensure that the trips that students take to school are both as safe as possible while being as cost effective to provide. The state of educational transportation has led to a fleet that is thoroughly lacking in data and sensors that could help reduce the cost per student and the safety of the students.

Lack of Data and Sensor Infrastructure

Due to the fact that school transportation is quite behind other areas when it comes to having more advanced vehicles that have many more sensors that provide data on the vehicle

(Schiess, 2017). According to a survey from School Bus Fleet, only a third of school transportation operators use GPS systems to help track buses. Nonetheless, roughly 40% of fleets have video cameras on buses. There is an all-around shortage of routing software, GPS, and student tracking technology with only 54%, 33%, and 5%, respectively, of survey respondents having such technology in their fleets (McMahon, Equipment Survey, 2015).

One of the other issues in terms of the technology has been a lack of ridership data. Gaining more information on the riders could definitely help school bus management companies and operators more effectively administer rides. “However, many districts base their ridership figures on eligibility, meaning that they account for all students who qualify for school-provided transportation, rather than the number of students who actually use the service. There are also many districts that only count ridership monthly or a handful of times per year” (Schiess, 2017). This problem has gone hand-in-hand with not providing student tracking systems to provide parents ease of mind while their children are in route to school.

Another challenge has been notifying parents of any issues with the bus itself. Quite frequently, it takes some time to identify a specific issue or to diagnose how long a fix might take. The lack of sensors and better communication around school transportation has been an issue in times of sudden change. There are three cameras onboard buses in Alleghany County inside that the schools can access and use in case of disputes. These can be used in times of incidents to look back and see what had happened, but there are few being used for improving the ride at the time. Frequently a single district can have to track a number of weather agencies and have to have quite manual procedural components to ensure what are the weather components on the local roads. This can make real time responses challenging in the current segmented environment (Humberston, 2017).

Environmental Concerns

One of the biggest arguments for school bus efficiency is the fact that school buses keep more than 17 million cars away from schools daily (National Safety Council , 2017). Just about all school bus fleet operators still have buses that run on diesel and a small amount have buses that run on one of the following: propane, compressed natural gas, biodiesel, and hybrid-electric (Diesel Technology Forum, 2017). This presents a clear environmental challenge.

The Vermont Energy Investment Corporation estimates that the full cost of an electric school bus is approximately $350,000, compared to $85,000 to $100,000 for a convention diesel bus. Electric buses can also offer benefits in the areas of: demand side management, vehicle-to-building integration (electric buses can provide energy to schools in case of emergency), vehicle-to-grid integration. (Morse, Malgrem, Wallace-Brodeur, & Whitaker, 2016). Though the expense structure of electric buses still has room for improvement, that hasn't stopped certain manufacturers from paving the way with what's possible. Canada-based Lion Electric Co. manufactured a 72-passenger bus that contains 5 batteries and can drive up to 100 miles on a single charge and can recharge overnight (School Bus Fleet, 2017).

Potential Future State, Near Term

Based on the current state of educational transportation outlined above, we propose a mixture of solutions focused on a) data and technology, and b) rethinking ownership and partnership. We specifically look into and review basic data capabilities, sensors for school buses, rethinking incentives around transportation, ride-sharing and microtransit solutions, electrification of school buses, and alternative ownership models and more regional focus.

Basic Data Capabilities

GPS systems that collect and report real time data are necessary in school transportation for both school managers and parents. For school managers, these systems could monitor the real-time location of buses and could help optimize the efficiency of the routes taken by buses. For parents, the system would report where the buses are taking their children and estimates of arrival time, and would disseminate notifications when last minute changes come up. Then adding RFID technology to help track students entering and exiting the buses would reduce safety issues such as drop-off mistakes and would also allow for immediate responses when such mistake occurs. Additionally, the combination of GPS and RFID system would both add peace of mind for parents and provide additional data for school districts on how transportation is being used.

Currently, there are a lot of companies providing GPS systems and student ridership systems for school transportation. Mostly, such companies sell their products to school and school transportation companies. Currently, a number of school districts across the country have adopted such GPS and RIFD card systems. For example, for 2017-2018 academic year, the Denver Public School system requires all school-bus-riding students to enroll in the +Pass RFID card ridership system (Denver Public Schools, 2017).

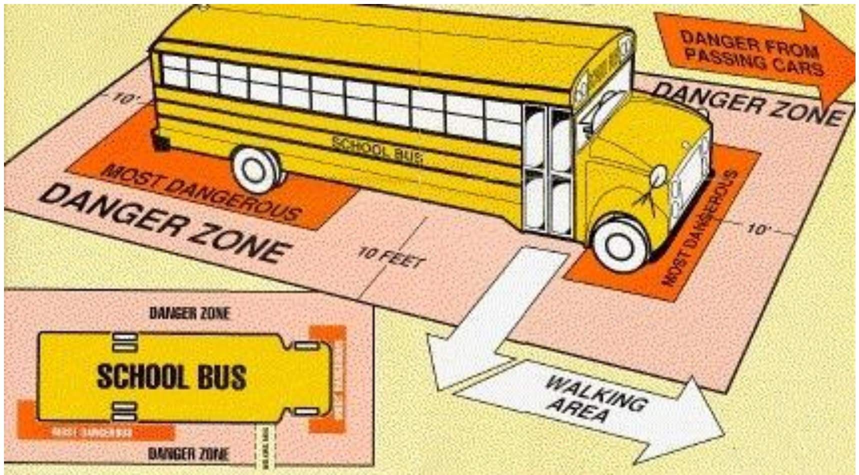
The cost of these types system has been a big challenge in their application considering the budgetary pressure of public schools, especially given that the system cannot generate direct revenues. Previously, the Aurora Public Schools provided zPass RFID card ridership services for K-8 students but only for K-3 students since 2015-2016 academic year because it is more cost-effective to provide these services for younger students (Aurora Public Schools, 2016). Additionally, given the lack of GPS's on school buses, it would be an integral first step to create a basis of consistent data across all school bus routes in the country. The total cost for school buses to be outfit with GPS systems should run in the vicinity of $80 million dollars without considering the system programming and maintenance cost[2].

Sensors & Student Management Software

Each year, there are 17,000 student injuries related to school buses and around 24% of them occur when students are getting on or off the school bus, known as being in the danger zone around the bus as shown in Figure 1 *(Stranford Children's Health, 2017)*. Given the difference in the height between younger kids and the school bus itself, it can be very hard for drivers to notice a young child in the danger zone. Therefore, it is necessary to install sensors around the bus to ensure that students can be automatically detected so that the bus stops in time to prevent injuries.

[2] The price of GPS units and services can range from $200 and up (GPS Insights, 2017). Assuming an average rate of $250, given that there are 480,000 school buses in the U.S. (American School Bus Council, 2017), and that roughly a two-thirds of school buses don't have GPS's (McMahon, Equipment Survey, 2015), the total cost comes out to approximately $80 million

FIGURE 1



Danger Zone, https://ossedc.wordpress.com/2014/10/20/national-school-bus-safety-week-is-october-20-24/

Currently, there are companies providing Student Detection Sensor Systems for school buses, such as Rostra. With microwave sensors installed, the driver would receive both audio and visual notification when students are detected in the danger zone (Editor, 2013). One of the main challenges in getting sensors added onto all buses is the cost that the sensors would bear, would total approximately $350 million to outfit the school buses that don't have such systems[3]. The actual rate could be smaller given bulk purchasing and the fact that more schools may already have sensors given previous legislations. This makes an approximate cost ranging from $400 to $450 million dollars to outfit buses with sensors and GPS systems.

When adding student tracking systems into the picture, the associated total cost of 'smartifiying' existing school buses goes up significantly. Based on a price quote from Treker, Inc., adding student tracking systems would have a fixed cost of $500 million and an annual cost of running the systems of approximately $250 million[4]. Thus, the total one-time upgrade cost would be in the vicinity of $1 billion with annual operations costs of $300 million. This definitely calls for better solutions around route optimization, reducing costs via private partnerships, and

[3] Assuming that the same amount of buses have sensors as GPS units (one third), the cost of outfitting a bus is roughly $1,200 (McMahon, Exterior sensors mandated on New Jersey school buses, 2016), and that there are 480,000 school buses in the U.S. (American School Bus Council, 2017), the total cost comes out $350m

[4] Based on surveys, only 5% of schools have such tracking systems (School Bus Fleet, 2016), which means that roughly 456,000 do not. Based on an email from the EVP - Business Development at Trekker, the cost per bus is $899 with a $5 per ID cost and a $45 dollar per bus monthly fee for data and support. Assuming a single ID per student, the costs come out as stated above.

driving down long term equipment costs, and rethinking ownership models. Taking a step back and realizing that total spending on student transportation totaled $24,164,005,000 in 2012, it's reasonable to consider a nationally coordinated private solution that could be priced out over a number of years to make the financial burden more manageable.

Optimization

A team of researchers from MIT worked on a bus route cleaning project. They used data from Google Maps and analyzed traffic patterns during morning and afternoon rush hours. Combining that with data provided by the Boston Public Schools on students and their assigned schools and respective routes, the researchers used mapping software and optimization techniques and devised an algorithm that would reduce the number of bus routes, reconfigure bus stops, maximize the number of students riding each bus, and cut the amount of time that empty buses were on the road. They also had to take into account that some students require wheelchair-friendly buses and others need home pickup.

Approximately 50 superfluous routes could be eliminated using the new method, saving the school district between $3 million and $5 million annually. According to a release, BPS transportation staff built school bus routes manually, using pupil transportation software — a multi-week process. MIT's solution devised routes in approximately 30 minutes. Besides, they also claimed that their algorithm could work everywhere (Baskin, 2017). Similarly, if they can apply real-time ITS systems, we expect that this kind of algorithm can work better in the future. Extrapolating the resulting from the MIT study, using such methods could save up to $3 billion and in turn paying for the aforementioned investments[5], as well as for ride-sharing and other alternative solutions.

Ride-Sharing & Microtransit Solutions

Ride-sharing, shuttling, and microtransit solutions all offer potential complements and alternatives to school transportation in certain areas where deploying school buses is ineffective. Currently, ride-sharing services have been used in school transportation to provide more flexibly

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[5] Taking an average savings of $4 million the fact that these savings were seen across 650 buses (Baskin, 2017), and that there are 480,000 total buses in the US (American School Bus Council, 2017), the total savings could be up to $3 billion, assuming that the same level of inefficiency is witnessed across districts.

in transport options. Generally, there are two kind of ride-sharing service companies. The first one is the school transportation version of Uber, such as *Zum*, which allow customers to customize a carpool with neighbors and friends.

Zum also provides full-time drivers with childcare experience, differentiating themselves further from traditional ride-sharing companies (Zum, 2017). Another kind of company like, *Carpool to School*, provides carpool platforms for school. The school-based carpool is maintained by the school and also includes ‘walkpool’ and ‘bikepool’ options for the parents to find other students for their kids to head to and from school with (Carpool to School, 2017). The Denver Regional Council of Governments (DRCOG) also provides schools and families with access to a “SchoolPool” program. SchoolPool matches families at a specific school or at nearby schools and families can organize carpools, biking or walking groups, or group travel via public transit (Schiess, 2017).

In certain areas, there has been some expressed demand from parents. “We heard from countless parents that there was a need for our service,” Joanna McFarland said, “given that 60% of kids live in households where every parent in the household works outside the home.” McFarland is the co-founder and CEO of HopSkipDrive, which is backed by more than $14 million in venture funding from FirstMark Capital, Upfront Ventures, Greycroft Partners, Pritzker Group Venture Capital, BBG Ventures and 1776**,** HopSkipDrive got a boost when it was chosen as a top 10 mobility startup at the Los Angeles Auto Show’s Connected Car Expo last year (Trop, 2016).

At the same time, ride-sharing services in school transportation are facing several challenges. Most ride-sharing platforms lack stringent background checks. While this may not present a problem for riders over the age of 18 ordering themselves a ride somewhere, it does pose a major challenge for parents when thinking of whether or not let their child ride with a stranger. The ride-sharing services mentioned above that are focused on families tend to have a more thorough background check, and some even requiring drivers to have childcare experience in order to give parents the peace of mind they look for when it comes to their kids.

Another challenge arises with the cost of these services. Based on a review of the companies above, the cheapest ride comes out to $7 (assuming a carpool). Given that a student need two rides per day and there are between 175-180 days of school in the U.S., that comes out to a lowest cost scenario of $2,450, which is a stark contrast to the per student cost of riding a school bus – roughly $950 as of 2013 per student transported (National Center for Education Statistics, 2017). It is important to note that while it's the schools that incur the per student cost with school buses, the cost shifts to the family when it comes to ride-sharing. This makes ride-sharing a feasible solution only for more affluent families with more disposable income.

This brings up a double edged sword of ride-sharing – it can offer access to geographies that generally lack public transportation or are more isolated, yet if there is no form of subsidy to support those financially struggling then ride-sharing only becomes a tool for a more privileged contingent of the population. There is the option that transit agencies can use a portion of their federal funding to help provide subsidies to those who need them the most and in turn reduce some of the transportation options that are experiencing lower ridership. Research shows that the average person is willing to walk a quarter of a mile to get to a bus and half a mile to get to a train. This kind of information can help plan the areas in which subsidies for transportation may be needed (Schwartz, 2016).

One alternative to ride-sharing is creating microtransit routes or by adding shuttles. Microtransit is the idea of privately owned and operated shuttles that would drive in a fixed route with minor route alterations possible in real time based on demand and traffic (Jaffe, 2015). A number of private companies have come up across the country working on providing vans along mostly fixed routes and many are struggling to make these projects make financial sense, bringing up the argument of whether or not transportation needs to be subsidized and thus a public solution (Berrebu, 2017).

Some school districts already provide school transportation options other than traditional school buses. Denver Public Schools have launched Success Express shuttles to help provide transport where there are no public transit options to increase school accessibility and "transportation flexibility". The Success Express shuttles drive around the neighborhoods with less transit access every 15 mites during peak hours before and after school on a continuous loop with defined stops (Schiess, 2017). However, the shuttle system faces challenges including shortage of drivers and generally low efficiency.

More than 25% of shuttle of a DPS fleet sits “idle due to a lack of drivers” and about 50% of all miles driven are without students on board (Asmar, 2017). Therefore, the shuttles occupancy and passenger ridership data should also be collected for route and efficiency optimization. Ideally, this data would be coordinated with school bus data and public transit data to ensure proper optimization for the city, not just for each transit provider independent of each other. The district replicated the Success Express model in 2016 with two new routes focused on middle school students in in west Denver. All of these routes stop at all schools in their area irrespective of the type. “DPS doesn’t provide yellow bus service for high school students outside of the Success Express regions, but instead gives a bus pass for public transit to high school students attending their neighborhood school if they live more than 3.5 miles away” (Robles, 2017).

Electric Buses

The environmental concerns of traditional diesel school buses could be solved by zero-emission electric buses. For years now, there have been a host of electric school bus pilot programs in California and other school districts across the country. However, the research around the cost of electric school buses generated has varied and frequently has contradicting results. The initial cost of an electric bus is much higher than traditional diesel buses, but the former has lower maintenance and operations cost compared to the later. According to some research, a V2G capable electric school bus would generate a net present benefit of $5,700 per seat without considering environmental externalities compared with diesel buses in a service life of 15 years. However, without V2G capability, the electric bus would generate $2,000 net present cost compared with diesel buses (Noel, 2014). A limitation of electric school buses is that they cannot be applied in cold areas because existing batteries cannot fulfill the power demand for heating the bus. Installing a diesel or propane unit in the bus could be a short-term solution (Schlosser, Can Electronic School Bus Go the Distances?, 2016).

On Nov 10 2017, Daimler, the parent company of Mercedes-Benz, announced plans to manufacture an all-electric school bus with a range of 100 miles for distribution in the US by 2019. Daimler says additional battery packs will be available for bus operators who want a higher range. Thomas Built Buses was able to draw upon Daimler’s electric technology resources during the development process, the company says. There are a number of smaller bus manufacturers working on electrification projects, but Daimler's Thomas Built Buses supposedly has a 38.7% market share in the US. That means there's a better chance that your kids will be riding to school in a Jouley than any other electric bus in the near future (Hawkins, 2017).

Overall, cleaner electric buses should be seen as a better option when it comes to replacing existing diesel buses, but large-scale application will be more realistic once the V2G technology and battery capacity technology improves and consequentially becomes more cost-effective.

Rethinking Ownership

One potential way to help the application of GPS system and sensor system and to improve school transportation efficiency and safety is to have state funding be issued to districts as rewards for efficiency and safety. For example, as shown in Figure 2, Florida Department of Education includes school bus occupancy as an index for school district transportation fund allocation *(Florida Department of Education, 2017)*. State funds could also be allocated as a reward for school districts running school buses without safety accidents.

FIGURE 2

Total Adjusted Students	x	Florida Price Level Index Factor	x	Average Bus Occupancy Index Factor	x	Rurality Index Factor	=	District Base Allocation Factor

Florida School Transportation Fund District Base Allocation Factor Calculation

This same thinking can be applied to private contractors. One school district is using GPS to utilize mileage and time reports as a basis for contractor payments. Using better technology with buses can make the management and ownership of buses more transparent and automated as well. By thinking about how to bring together various private companies and public transport authorities, it is possible to create incentive structures that will ensure the end users wellbeing. It's easy for private contracting to go wrong if the appropriate checks and balances are not in place, but creating the right private-public partnerships can truly offer new possibilities between school districts, states, and alterative solution provides. This would definitely face challenges from a policy perspective given the fact that education is a state policy. At the same time, this could offer an opportunity with states running variations of public-private partnerships and sharing lessons learned to find what works best in the long run.

Engaging the Public in New Ways

Finding new ways to engage public talent is also an important factor that can help cities and states innovate. It's possible to organize hackathons or create partnerships with universities to study the potential and current affects in certain areas. For example, Boston holds a computer science challenge to improve their school bus routes, and to in turn rebalance their bell times with the goal of freeing up transportation spending to use on other educational elements (Boston Public Schools, 2017). Other cities open up their data for hackathons such as Big Apps NYC in New York to find new ways to engage with entrepreneurs and local tech talent. These events can create communities that can help come up with new solutions and should be encouraged.

In the short run, GPS tracking and RFID card-based ridership system and sensor installation on school bus are proposed to improve school transportation in terms of efficiency and safety, though at a reasonable but worthy cost. Rider-sharing services and shuttles are also encouraged to increase the flexibility and cover the unavailability of school buses in certain areas, if the former is well regulated and the efficiency of the latter is improved. Zero-emission V2G capable electric school buses are proposed to replace diesel buses in warm area with sufficient budget, or when the battery capacity increases and cost decreases as technology develops. Adding coordination across more regional authorities & allowing for maximum usage of optimization would help innovate the school transportation ecosystem while cutting costs as much as possible.

Potential Future State, Long Term

Autonomous Buses

Despite many of the advances in autonomous vehicle technologies, one the frequently understated challenges related to the topic is people's reticence for riding in fully autonomous vehicles. With some preliminary research being done in the space, upwards of 30% of people that they "would not consider" using AVs for their trips (Kelley, 2017). In a Pew Research Survey, 53% of respondents where very or somewhat worried about autonomous technology (Smith & Anderson, 2017). This shows that most Americans are still not confident enough with the state of the technology to be willing to ride in AVs, much less let their children to. It can be imagined that if larger AVs are used to transport students then there would still be someone onboard, more in the role of a guardian or caretaker than that of a driver.

Options like Teague's Hannah (cover image) challenge the idea of large buses, presenting the design of smaller autonomous vehicles that can travel in either direction and pick up students at their homes. The logic of smaller vehicles would be that it would be easier to customize routes and limit the amount of time spent on travel overall (Marshall, 2017). These resources all point to the reality that these vehicles may not see real adoption for 10-15 years depending on the costs and the policies relating to transportation across districts. Much of the planning and projections in this area are still theoretical, so it is hard to accurately estimate the amount of time necessary for this technology to develop.

Research in other areas of autonomous buses and shuttles can show some of the potential benefits of using this technology on a city-wide basis. Electric bus company Proterra has partnered with the University of Nevada, Reno to examine a deployment of such a bus in the city. Since January 2017, data has been gathered pertaining to how to best integrate the autonomous buses into traffic on Virginia Street in Reno. The first phase focuses on adding sensors that can detect what's going on at the intersections ahead to the semi-autonomous buses. This phase is expected to last a year and will help set the stage for the potential of further integrations (Poon, 2017), despite some similar projects experiencing challenges from the onset. A fender bender with an autonomous bus in Las Vegas reminds that there are still improvements to be made in the AV tech itself. It also highlights how public concern can arise even around the smallest of accidents (Shepardson, 2017).

Daimler has rolled out the Mercedes-Benz Future Bus that travels 20 kilometers in a project with CityPilot. It goes from Amsterdam's Schiphol airport to the town of Haarlem, Netherlands (Daimler, 2017). Though not all options will be that luxurious, it's far from being the only pilot being run. In September 2017, a street was closed down in Bloomington, Indiana to run a free autonomous bus for residents (Herald-Times, 2017). Finland plans on rolling out a consistent autonomous bus route following an early trial that went successfully in a small town north of Helsinki. The bus still has someone there in case of emergencies, travels a quarter-mile route at 11 kilometers per hour, and carries 12 people (Sisson, 2017). The same type of bus has been trialed in Taiwan, on National Taiwan Universities, since May and has excited individuals about the potential of a further roll out (Horton, 2017).

Conclusion

As seen here, the landscape surrounding transportation in education is quite complicated. Between dated fleets, a complex funding landscape, and technological challenges just to name a few, it is clear that much change is needed to bring school buses into the 21st Century. We believe the solutions lie in a two-step approach: focusing on the school buses themselves, and on the ownership and management of them. In terms of the school buses, it's critical to go through some hardware upgrades involving GPS sensors, RFID based student tracking systems, and sensors to limit the amount the accidents. As outlined above, this would have a fixed cost of approximately $1 billion and annual costs of $250 million.

These upgrades would have limited impacts if the buses were not being coordinated across more than just school districts. This would open the way for easier integration with public transportation as well as private solutions. This could involve either state-wide coordination, completely outsourced solutions, or the creation of public-private partnerships that involve coops or consortiums of school bus fleets across counties and states. This would make for more efficient collection of data and administration of fleet optimization solutions across all organizations involved in student transportation in any area. We believe this would create the right foundation for electric and eventually autonomous vehicles to be effectively administered once the respective technologies advance enough.

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