Planning and Scheduling for Electric Vehicles

Electrifying your public transportation fleet isn't (only) about hardware choices

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Introduction

Are electric vehicles all about choosing "hardware"?

The electrification of public transportation may be slow, but it's bound to happen. All over the world, cities and governments look to electric vehicles in public transportation to reduce pollution and make cities cleaner. Major capitals are creating ultra low-emission zones or requiring full electrification of public transportation in the future.

Most experts focus on "hardware" choices: the buses, batteries and chargers agencies and operators should purchase. It makes sense to ask those questions: EV deployments are expensive and there is a need to mitigate risks, to not discover that the ranges, charging requirements or vehicle count required for a given service is different than planned. However, modelling this accurately will probably require software.

Indeed, what is often overlooked is the need for software to properly plan for and schedule EVs. Many legacy scheduling platforms do not support EV requirements, yet EV planning and scheduling pose complex challenges. If battery levels, charging speed and capacity as well as trips to charging locations aren't taken into account, the results will be sub-optimal, increasing the risk of failed EV implementations.

The Challenges of EV Scheduling

The successful adoption of EVs into public transportation is dependent on our ability to optimize the resources available to us while complying with the new constraints created by charging requirements. Doing this with the help of advanced algorithms can allow us to create public transit that maximizes operational efficiency, while reaping the benefits of carbon independence.

As a result of battery range limitations, EVs need to be recharged throughout the day and, at the very least, planners must form a charging strategy compatible with available infrastructure. This introduces new challenges to the planning and scheduling process. Because suboptimal recharging threatens to increase the number of vehicles required to operate a timetable (and therefore increase operational costs), optimizing charging events is essential to create economically-viable electric transportation solutions.

Deciding when, where, and for how long to recharge electric vehicles is dependent on several variables:

1. Available charging infrastructure: The availability of in-depot and opportunity (i.e. en-route) charging varies from agency to agency. As a result, travelling to chargers (by way of a deadhead) and the capacity of such charging infrastructure needs to be taken into account.

2. Charging needs of the fleet as a whole: Schedulers must consider when other vehicles are charging. Having too many vehicles charging at one time can force agencies to use extra diesel buses to account for those EVs temporarily out of service.

3. Electricity pricing: Because electricity pricing varies throughout the day, much more so than diesel or natural gas, taking advantage of low demand (and thus low cost) times is key to minimizing operational costs.

Two important concerns factor here:

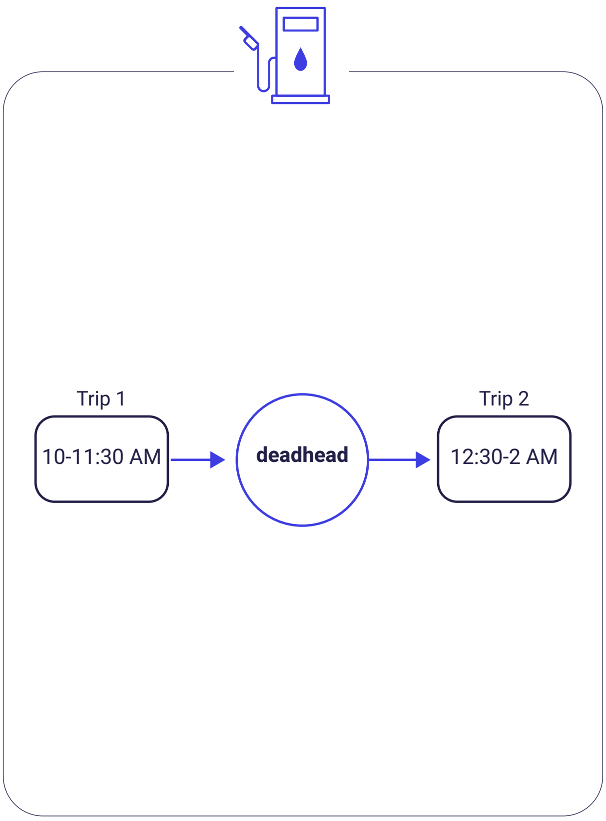
Range anxiety is when there are fears that the remaining battery levels are low enough to run out of power in the middle of a trip. This fear can lead to overly cautious scheduling that hedges against this - it isn't a good practice to follow. The discharge rate for batteries isn't linear, and often batteries behave differently than appears in OEM specifications. Additionally, ranges are also affected by weather conditions, ridership, road conditions, driving styles and more. However, scheduling can account for this, setting the right thresholds, preferably based on real-life information from the networks, and making sure that these thresholds aren't exceeded.

Insufficient "electric miles": in principle, the goal of any EV deployment is to service as many "electric miles" as were previously served with a fossil-fuel based vehicle fleet. When there are too many charging events, or they are inefficient, require excessive deadheads or layovers etc, the fear is that the EV buses will serve less "electric miles", or require more buses to offer the same "diesel miles".

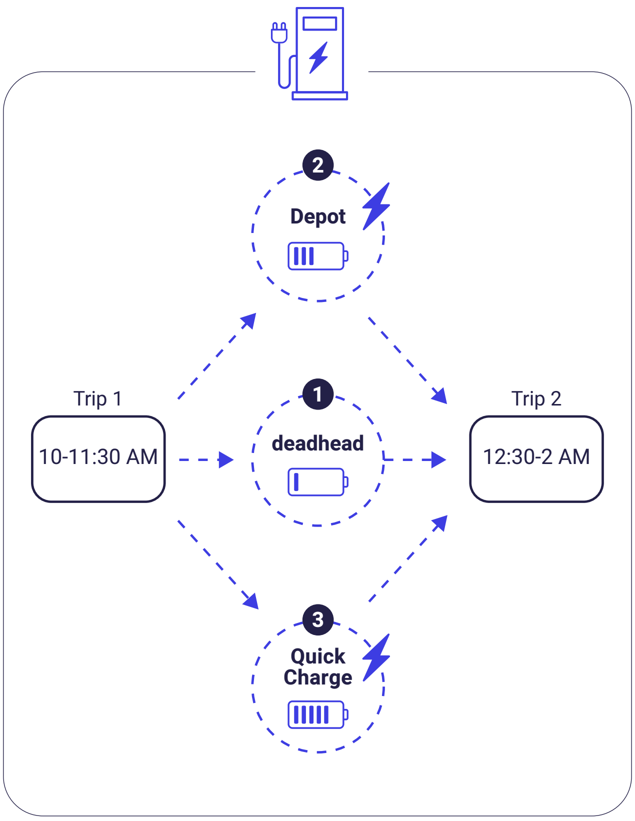
An algorithmic perspective

Let's look at the algorithmic complexity of optimizing charging events to understand the technology challenge.

We can model a transit system as a network of possible connections between compatible trips (whose times don't overlap, are the same vehicle type, and therefore can be driven by the same vehicle). Here's a simplified example:



Traditional Vehicles



Electric Vehicles

If we zoom in on the connection between two compatible trips, we can see what makes optimizing EV scheduling so difficult.

For traditional vehicles, we only have one option for connecting two compatible trips: a deadhead. So, our goal in optimizing scheduling with traditional buses is to connect all trips with the least number of buses possible, while minimizing deadhead cost.

The electric vehicle scenario gives us a much more complicated model. This is because we might have more than one option when connecting two trips. In our example, each connection has three options: complete a deadhead to the next route immediately, charge at the closest in-depot charger (with deadheads on both sides of the charging event), or charge at the nearest opportunity charger (possibly with deadheads on both sides of the charging event, depending if the opportunity-charger is en-route). We now want to minimize peak vehicle requirement, deadhead costs, and charging costs (electricity and time) with the addition of two new constraints: each bus must have enough charge to complete its trips and there are a limited number of chargers that can be used at one time. Because these constraints involve the entire system, not just one connection between two trips, advanced algorithms are needed to support them.

The importance of scenario planning

The ability to easily express preferences and constraints with regards to electric vehicles, on a simple interface, as well as be informed (through a validation mechanism) to know when batteries are depleted, can help create different scenarios. For instance, a scenario considering different locations for chargers, different routes served by EVs, quick or slow charging etc. You can also check the impact of setting different minimum battery levels and more.

Scheduling for mixed fleets

Often, EV adoption begins gradually, when several electric buses are purchased and used within an existing bus network. Since most scheduling systems do not support scheduling electric buses alongside ordinary buses, there is a tendency to try to simplify the problem and relegate electric buses to certain routes or only to be used only during peak times and charged during non-peak hours. This approach isn't recommended, since it does not maximize electric miles, as it usually under-utilizes electric buses and is mostly a result of range anxiety. Under utilization means a high vehicle requirement, with a resulting effiiciency degradation.

We recommend scheduling mixed fleets while taking into account two vehicle "groups". This creates a solution that considers the different costs associated with different vehicle types and optimizes accordingly. In cases like these one can create hierarchies, preferring one group over the other, taking EV and battery type into account.

Charging strategies & planning for charging types and locations

Often, some of the most important questions with regards to electric vehicles are related to charging, planning for charging locations and charging strategies. Typically, agencies have two types of chargers.

Fast chargers are located in high-density areas, charging up buses in layover locations quickly.

Slow chargers charge at a slower rate, and are usually used when the bus is in the depot.

Agencies and operators need to make decisions about which charging strategies are better, for example, comparing a quick charge strategy with a slow charge one. The main point here is that there is no correct answer with respect to charging. The results depend on the network, the layovers, the route lengths, timetables and more. The KPIs of each scenario as well as changes to the PVR will provide the response. Agencies should input all relevant information into the scheduling platform and create multiple scenarios, to arrive at the best possible solution.

To do so, we need to be able to easily define the following:

- Charger location, type and the capacity for simultaneous vehicle charging
- Charger profile ID
- Battery types supported
- Minimum Charging Time
- Charging rate in kwH/min
- Maximum level of charge (%)

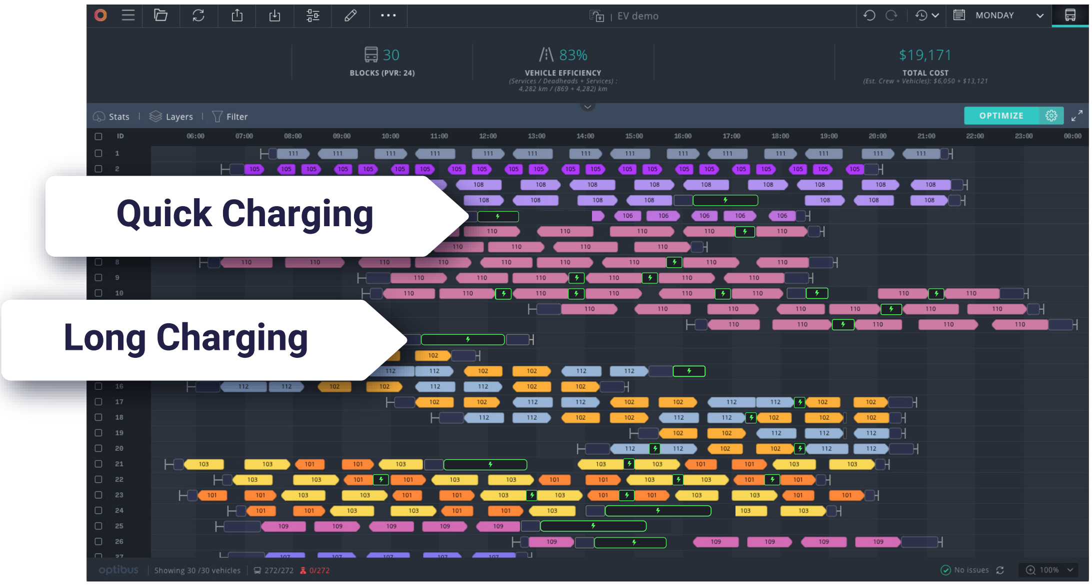
As the mixed fleet grows and more chargers are needed, scheduling can be used to plan for additional chargers and methods.

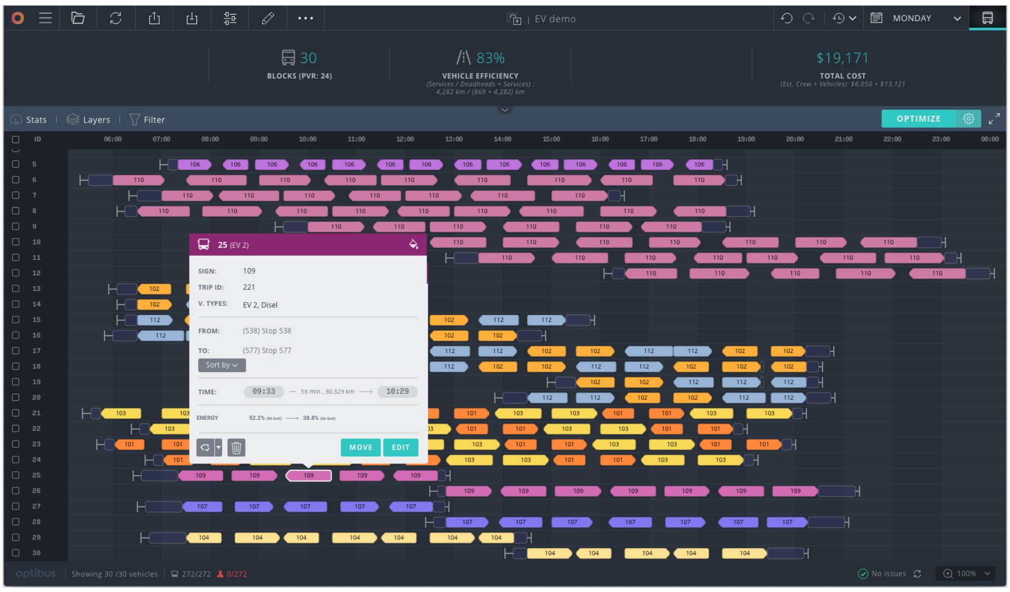
Scheduling for 100% EV fleets

When the entire fleet is electric, more considerations may need to be made, such as matching breaks to charging events and further optimizing charging and battery levels.

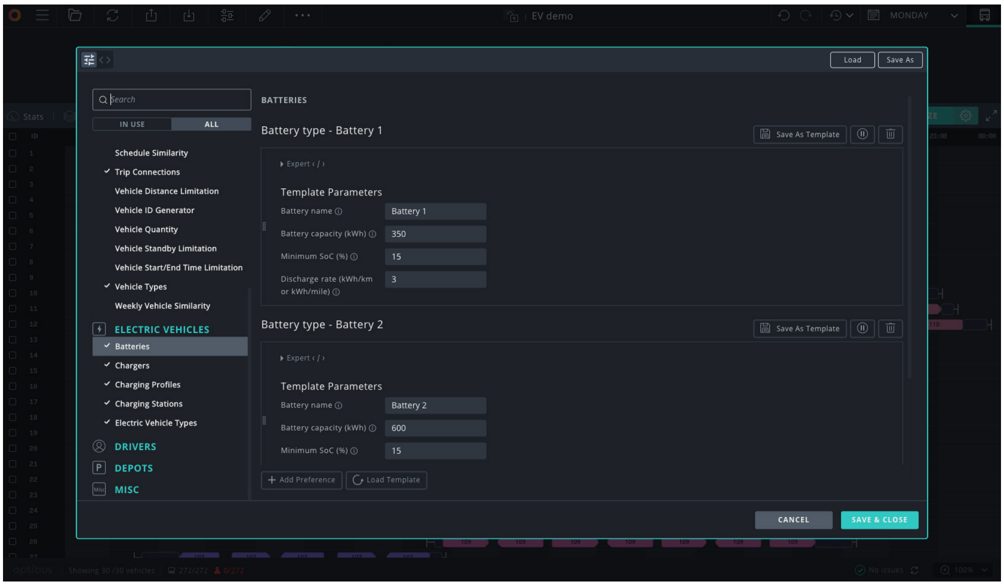
Here are some examples of 100% EV schedules.

Indication of long and short charging events:





You can click on a trip to instantly see current battery levels and make changes as needed. Optibus even allows you to set a minimum percentage the battery has to stay at the whole time, guaranteeing EVs the longest routes possible.



An easy-to-access settings window allows you to input the proper discharge rate for the battery.

Conclusion

Using electric vehicles in public transportation presents unique challenges on both the "hardware" and "software" sides, requiring agencies and operators to change old habits and tools. The technological change on the hardware side and the algorithmic and scheduling challenge on the software side will transform agencies. There are numerous benefits to this change. Modernizing planning and scheduing is a digital transformation that will benefit drivers (through better work-life schedules), the public (better service reliability) and the environment, through electrification.

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Optibus is a cutting-edge software platform that powers complex transit operations in over 300 cities around the world. A cloud-native SaaS company founded in 2014, Optibus is headquartered in Tel Aviv and has offices in New York, Chicago, Seattle, San Francisco, London, Düsseldorf and São Paulo.
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