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VIEWPOINT

A NEW MODEL FOR EV CHARGING STATION OPERATION

The electric vehicle revolution is stalled due to mindset, supply chain and infrastructure challenges. Value-adding services at charging stations can help overcome infrastructure challenges. One approach is the Theory of Constraints, which involves implementing strategic buffers before charging.

Infosys | Knowledge Institute

Governments have announced deadlines to phase out internal combustion engine (ICE) vehicles, and manufacturers have announced plans to stop producing them. The gauntlet is already thrown down, and there is no going back on the road to zero emissions. But issuing an edict does not guarantee a solution. A study commissioned by Infosys with PAC GmbH to understand the electric vehicle (EV) market found price and range anxiety as the most significant impediments to EV adoption. This article discusses how Theory of Constraints (TOC) principles can be applied to improve the EV charging station experience and accelerate adoption.

A fragmented charging landscape exacerbates range anxiety. The lack of charger standardization across the automotive ecosystem hampers the pace of EV adoption. Meanwhile, current EV charging loads, especially at peak times, place an additional burden on the electrical grid. A recent Stanford University study estimates peak electricity demand to increase up to 25% from rapid EV growth in the western US in a decade. This implies utility companies need to invest in additional renewable energy sources.

An estimate shows the number of charging stations in the US needs to triple from the current 56,000 by 2030. That volume may be achieved through private investments and the $5 billion program announced by the US government. The program will create 500,000 new charging stations in the next few years, more than three times the 145,000 gasoline fuel stations in the US today.

Investments like this will primarily address the driving range issue. However, will simply adding many more charging stations be sufficient? Charging stations are a service, and as EV sales grow, battery charge time will become the bottleneck. A quick calculation demonstrates this problem.

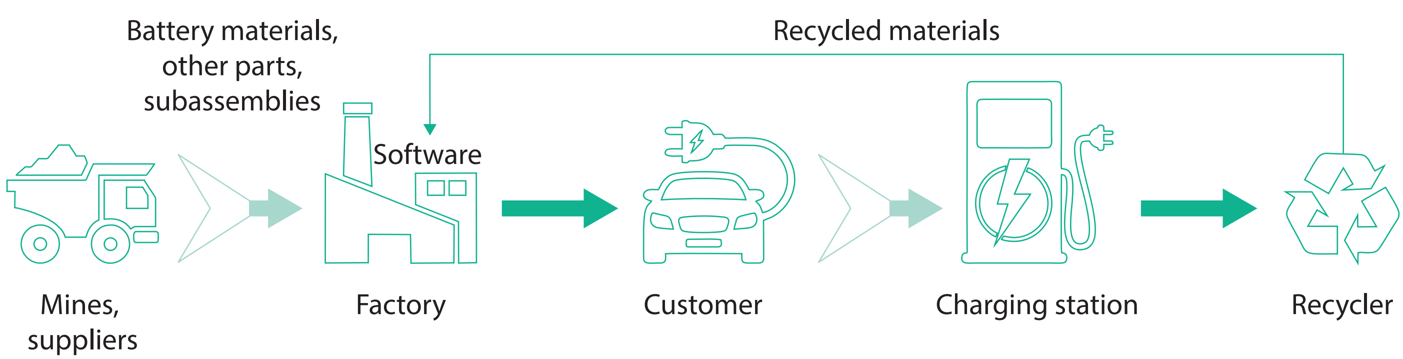
An EV charge is more than three times longer than refilling a combustion vehicle, even considering the fast-charging option (and the 480V setup requires serious infrastructure). With traditional queuing models, this EV charging "time penalty" creates a powerful disincentive for travelers in a hurry. However, using Eliyahu Goldratt's TOC, charging stations can create strategic buffers that avoid congestion and increase throughput.

Batteries and affordability

The major constraints for EV affordability and access are the supply of battery materials and the charging stations to charge those batteries (Figure 1).

In 2021, US EV sales passed 5% of new automotive vehicles sold. The US government has established a zero emission (aka EV) new vehicle sales target of 50% by 2030. This 10-fold increase in vehicle volume translates to a corresponding increase in battery material demand. Nearly 400 additional mines for graphite, lithium, nickel, and cobalt may be needed by 2035 to supply all those new EVs. Even if recycling is considered, the number of required mines is still in the low 300s.

Figure 1. EV value chain and major constraints



Source: Infosys Knowledge Institute

Alternate battery materials and technologies offer a promising approach to address this constraint. Solid state batteries and alternate materials for cathodes and anodes are research-oriented approaches that need investments in facilities and human capital. Battery rental and usage-based billing provide innovative business models and economies of scale with bulk material procurement.

EVs are expected to reach price parity with ICE vehicles by 2026, based on battery material procurement. Battery price curves have raced downward over the past decade, with inflation-adjusted prices for car battery packs falling from $1,200 per kWh in 2010 to $132 per kWh in 2021. Bloomberg estimates EV price parity at $80 per kWh by 2026 in the US and Europe.

EV pricing includes battery cost, so decoupling it from the price significantly decreases a vehicle's total cost. Decoupling a battery and offering it as an option to swap will change charging stations from a pure service model to a product-based approach.

Product play with battery swapping

Battery swapping stations are an effective, time-saving approach to mitigate bottlenecks at charging points. Rather than recharging a battery, an already charged battery is swapped. Drained batteries are charged in the background, at an efficient rate and in ideal conditions, minimizing the potential for overheating and using renewable energy to the maximum.

Professor Ferdinand Dudenhoeffer, Director at the Center for Automotive Research at the University of Duisburg-Essen, Germany, believes that European car makers are missing an opportunity by ignoring battery swapping. By comparison, Chinese car makers plan to establish 24,000 swapping stations. Battery swapping has the potential to sweeten the charging station business model. Automotive mogul Chetan Maini, who built India's first electric car, says that battery swapping is the way forward for safe, affordable EV adoption on a large scale.

TOC and charging station buffers

Removing charging process bottlenecks is another way to improve the EV charging future. TOC, already well known in manufacturing, applies to charging stations too. In fact, TOC adds value to the consumer wait time and increases revenue for charging station operators.

TOC's signature characteristic is to identify production bottleneck resources and optimize their efficiency to increase end product throughput. The resource that has no excess capacity and thus limits overall system output is the bottleneck (constraint). The processing time at this machine or asset determines the overall cycle time. Improvements to ease this constrained resource will directly increase the overall output, while increases at assets with excess capacity (non-bottlenecks) may have no impact on overall output. The constraint is also referred to as a drum, "beating" in a cadence that determines system flow and output and is integral to the TOC technique of drum-buffer-rope.

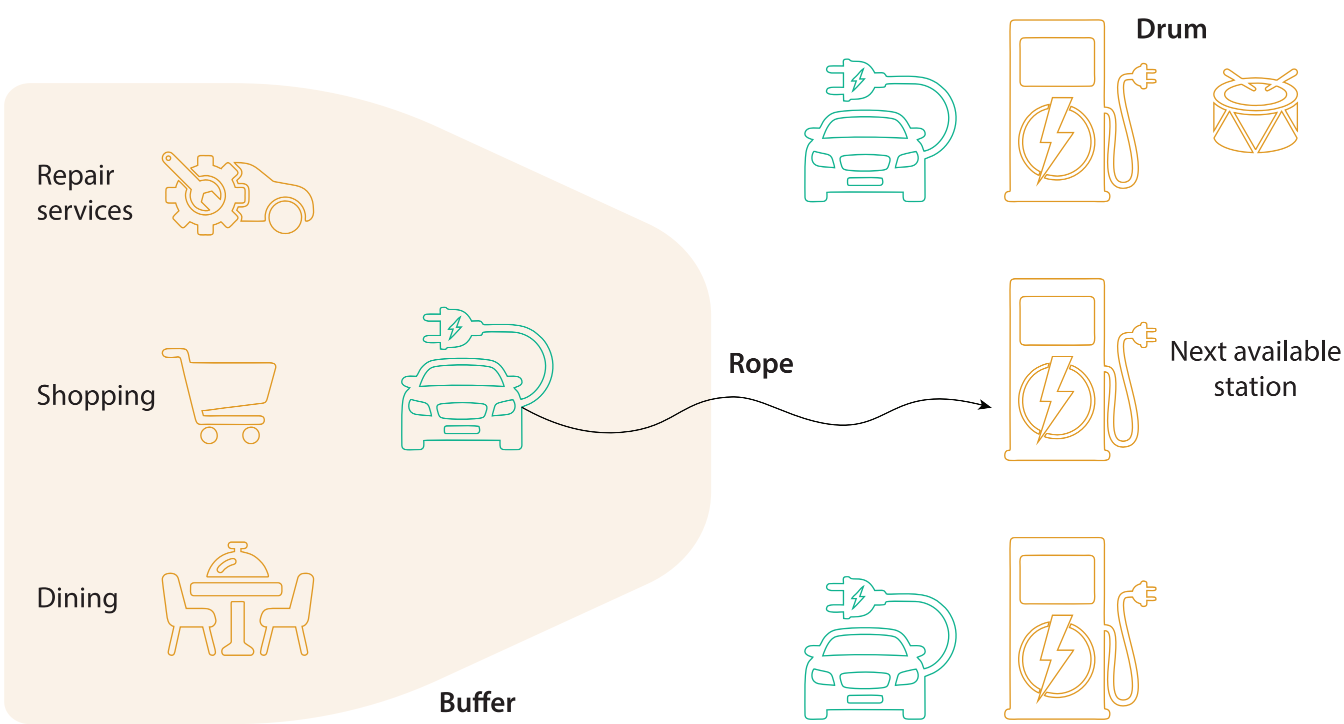
The drum and its rate establish the pace for the rest of the shop floor or operational system. Delays at this machine cause a reduction in overall finished goods output. The charging station is the drum in the EV value chain. The battery charging pace determines the output rate of the overall charging experience. Emerging battery and charging technologies will reduce the charge time going ahead, yet it will remain a constraint. Each minute at a charging station is valuable, so it is important to make sure no time is wasted waiting or charging.

Upstream buffers optimize capacity by creating time at the constraint. Buffers can also be value-added experiences — at a restaurant, store, or a maintenance and repair station — for customers waiting at a charging station (Figure 2). Buffers can cushion the variations in the arrival at each station.

> TOC's signature characteristic is to identify bottlenecks and optimize their performance to increase throughput

The rope in drum-buffer-rope controls work releases at a pace that does not overwhelm the bottleneck. For charging stations, the rope can be the information flow that allocates the next car in the buffer for charging, depending on battery charge remaining. When a car enters a charging station, its position in the queue could be decided based on the remaining charge or the consumer's intended activity while waiting at the station — shopping, dining, or repair. Also, premium customers could be given priority in the queue. Whenever a charging station is available, the next car can be signaled to move in place at the charging slot, avoiding idle time at the constraint.

Figure 2. Buffers before a charging station to avoid wait time



Source: Infosys Knowledge Institute

An ecosystem approach for EVs

In an earlier publication, we discussed how an ecosystem approach is important for the EV sector to succeed. Upstream buffers in the battery charging approach are crucial in this ecosystem. Investors should consider buffers in the detailed planning required prior to the set up. Charging station configurators provide a structured approach to financially and operationally manage these important EV network nodes.

> Upstream buffers create capacity at bottlenecks, ensuring maximum utilization

The EV ecosystem is a long-term bet unfolding on a global scale, a once-in a-century mobility revolution impacting nearly every citizen. Countries and even regions or local government leaders should consider the overall impact while planning and implementing the ecosystem. Battery swapping requires close coordination between vehicle and battery manufacturers to ensure interoperability but is currently difficult to achieve. TOC is one approach to mitigate charging station implementation risks, even without such coordination between competitors. While the EV industry evolves, TOC is a practical model to roll out the electrification of mobility at scale.

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