

COLLECTIVE POWER:

FUELING THE FUTURE OF HEAVY-DUTY ELECTRIC VEHICLES WITH **COMMUNITY CHARGING HUBS**

WHITE PAPER

JULY 2024

e-Embarque

 Log-hub
data driven innovation

 PANION

 WHU
Otto Beisheim School of Management

FOREWORD

Our newly launched e-Embarque initiative aims to accelerate the electrification and decarbonization of heavy-duty electric vehicle fleets in the logistics sector. Our recently published e-truck ranking shows that the electric adoption is underway, although many operators are still in the early experimental stages with only a few test vehicles. The challenge now is to transition from these initial tests to a large-scale operation of electric trucks. We expect community, semi-public charging hubs to be one of the key enablers.

In this first article in a series, we present our overarching perspective on market players, the total cost of ownership, and potential future benefits of community charging hubs .

e-Embarque



THE CHARGING INFRASTRUCTURE CONTEXT

As clearly outlined by the German Council of Economic Experts in their Spring Report 2024, [1] a critical factor in achieving scale is the rapid development of a comprehensive charging infrastructure for battery electric trucks.

To achieve the ambitious goal of converting one-third of heavy-duty mileage to electric power by 2030, it will be critical not only to deploy high-speed charging stations along highways, but also to integrate semi-public and private charging hubs at locations such as depots and cross-docks. [2] In particular, depot charging could be a cost-effective solution, especially when combined with on-site renewable energy generation through photovoltaics (PV).

Currently, the range of electric trucks is still limited, making them best suited for regional operations and private depot charging facilities with charging speeds ranging from 150kW to 500kW. [1] Eurostat statistics show that in 2022, more than 40% of all road transport routes in the European Union were less than 300 km in length. [3]



In addition, private depot charging is specifically supported by public incentives for the installation of commercial fast-charging stations, for example with an additional €150 million of public funding available in Germany since June 2024. [4]

Depot charging can occur at production facilities, warehouse locations, ports and large retail outlets. Some, if not all of these locations need to be equipped with charging infrastructure, as hundreds of trucks visit each day. Typically, these logistic locations are clustered as hubs, i.e., there is a number of such locations all clustered into a fairly small patch of land. These hubs can be used for community charging, whereby multiple logistics players share the same charging infrastructure.

To ensure a smooth, scalable operation of community charging hubs, logistics industry specifics have to be considered, such as the integration of charging during legally required breaks, charging while waiting or loading at cross-docks, and the increased number of parking and charging spaces needed for charging vehicles.

Dynamic reservation and optimization systems for charging infrastructure are beginning to be implemented and will become increasingly important to reliably plan and update charging sessions that fit into existing transportation schedules and stay aligned with route execution and traffic conditions.

The transportation industry is highly cost sensitive [1] and without such systems, already tight margins for transportation companies will deteriorate further, making the transition to e-mobility virtually impossible. These systems will have to manage an increasing amount of charging-related data, including infrastructure data, charger occupancy and reservation data, as well as vehicle data such as battery capacity, current and desired state of charge (SoC), and required charging power. [5]



MARKET PLAYERS COMPLEMENT EACH OTHER

in their EV charging focus and their parking, reservation and dynamic optimization capabilities

In our view, the complementary capabilities of five types of market players along the dimensions of electric vehicle (EV) charging, and parking, reservation, and dynamic optimization are essential for the successful establishment of community charging hubs and their integration into electric truck operations:

1

CHARGE POINT OPERATION CAPABILITIES – including asset management, billing and reconciliation, as seen in e-Mobility Service Providers (EMSP) and Charge Point Operators (CPOs).

2

HARD- AND SOFTWARE – providing the fundamental charging station infrastructure needed for reliable and convenient charging.

3

DYNAMIC AND INTEGRATED CHARGE PLANNING – coordinating charge slot assignments in real-time, based on available charge stations, grid limitations, as well as vehicle arrival times and charging needs.

4

RESERVATION INTERFACE AND TECHNOLOGY – including established truck parking platforms that already broker private parking, reservation and rest opportunities today.

5

OPTIMIZED ELECTRIC VEHICLE ROUTING – optimizing transportation routes that minimize travel time, distance, and charging costs under battery capacity constraints.

In Figure 1, we have clustered promising market players in this ecosystem by assessing their maturity at the intersection of EV charging and parking, reservation, and dynamic optimization systems. While passenger EV charging solutions are well established, the heavy-duty vehicle charging market is still in its infancy, with a current focus on light commercial vehicles and last-mile delivery use cases. We therefore expanded our focus to also include market players that are likely to move into heavy-duty community charging and reservation or dynamic charging systems in the future.

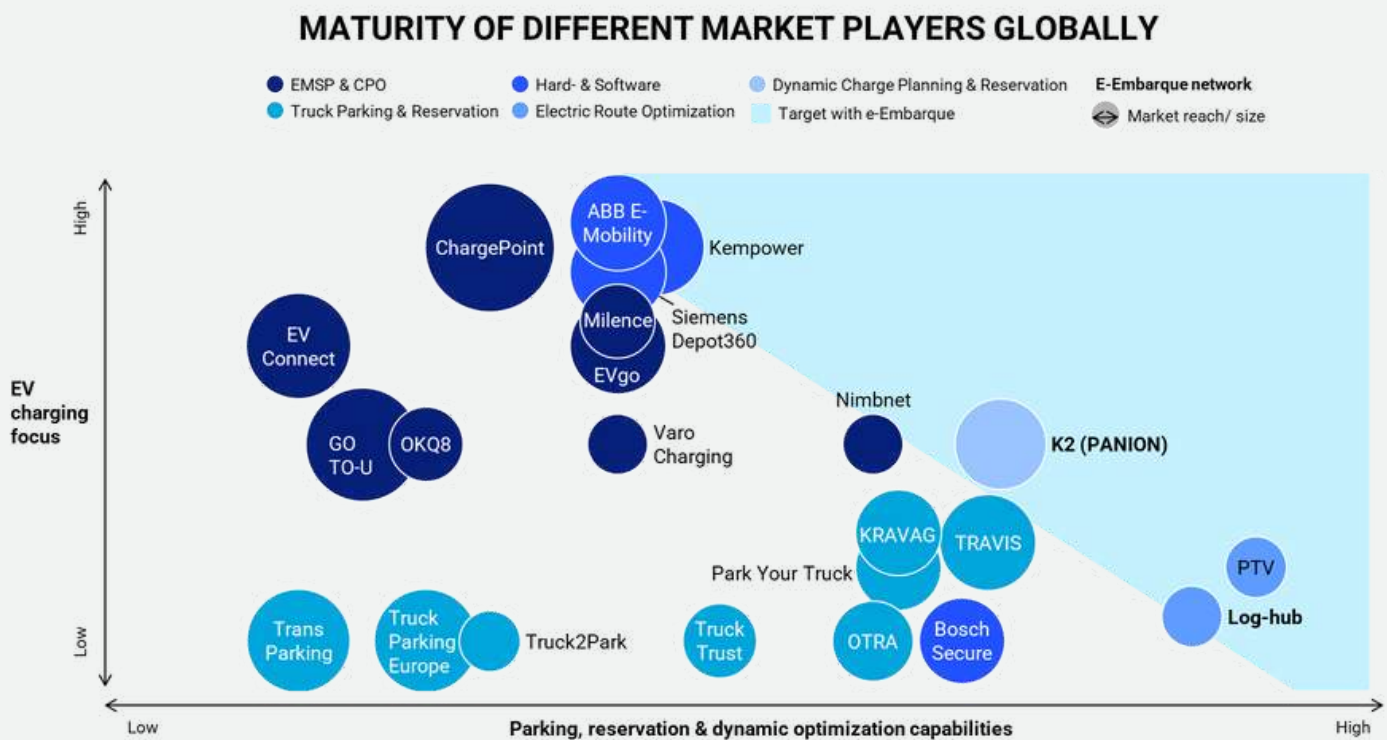


Figure 1: Clustering of market players based on expert assessment and research by e-Embarque

To name a few promising EMSP and CPO examples, Milence and Nimbnet are new market entrants with a primary focus on heavy-duty vehicle charging. In addition, well-established players such as ChargePoint and EVgo, which have extensive passenger EV charging networks, are diversifying into the heavy-duty vehicle market. Their initial objective is to address the public and en-route charging requirements of fleets, a strategy that aligns with that of major players in the passenger EV market.

A major challenge for logistics fleets is the asset downtime while charging. This is further amplified by waiting times at public charging stations when the desired charge point is occupied by another truck.

As a result, reserving public charging stations en-route and dynamically adjusting them based on truck SoC and traffic conditions is critical for logistics companies to move beyond short-haul EVs.

Providing visibility into slot availability and managing related reservations is an issue that parking management solutions have been addressing for several years. Truck parking and reservation players such as TRAVIS, KRAVAG Truck Parking, Park Your Truck or TruckTrust manage the capacity of independent site operators.

Subscribing truckers can easily book parking spaces for daytime driver breaks, waiting periods, and overnight stays with one of the independent site operators and use the amenities available at the site. While information on exact location, amenities, booking status and pricing is typically offered through their digital booking platforms, and sometimes integrated with fuel card payment solutions, e.g., by TRAVIS, parking reservations are not dynamic and do not automatically adjust to changes in truck arrival or departure times.

A dynamic charge planning and reservation system such as [K2 Mobility's PANION software](#) provides this coordination function: an algorithm that aligns and optimizes supply and demand, which is a core functionality in the context of shared infrastructure.

Based on the operational requirements of the vehicles and the available resources, it ensures that all vehicles are being sufficiently charged, at an attractive price and with little to no waiting time. It connects to the trucks as they approach the charging station and constantly updates the reservation, ensuring that it takes into account delays as well as early arrivals. It also keeps an eye on the SoC of the arriving truck's battery to adjust the time and/or power of the upcoming charge session to ensure that the truck has the level of charge it needs before continuing on its journey.

To cost-effectively integrate electric vehicles into a fleet, dynamic optimization of electric truck routes is required, and analytics platforms such as [Log-hub](#) provide a solution. Advanced mathematical models account for the operational complexities of electric trucks and charging stations, including battery capacity, charging times, and infrastructure accessibility, to minimize operating costs and travel time while meeting customer demand.

Through our [e-Embarque initiative](#), we aim to bring together the complementary capabilities of all five types of market players to collectively achieve a high level of maturity in EV charging and parking, reservation and dynamic optimization and to work towards the target space shown in Figure 1.

TOTAL COST OF OWNERSHIP IS TOP OF MIND

In our discussions with fleet operators and charging providers, as well as in our academic research, we continue to see that the Total Cost of Ownership (TCO) is the most important factor when logistics companies plan their vehicle electrification. Respective questions build on the high-level guidance available online [6] and further focus on the practical scalability of electric truck charging hubs.

In evaluating the potential for fleet electrification, most [fleet operators](#) initially conclude that since the purchase prices for electric trucks are three times those of diesel trucks and consequently, the TCO is never going to work out. There is, however, a lack of reliable reference on TCO in scaled electric fleets, with most knowledge being based on one, two or three trucks in occasional operation. A comprehensive TCO analysis should consider not only acquisition costs, but also potential savings from lower cost of operations, such as the cost of energy, waived tolls for electric trucks, local electricity generation, and maintenance costs which can be up to 50% lower than for comparable diesel trucks. Furthermore, logistics companies can bring charging infrastructure cost down by engaging in neighborhood community charging hubs.

Given the very low utilization of charging infrastructure in single site installations, the [TCO for electric trucks can be further reduced by up to 30%](#) through a community-driven doubling of charger utilization and a moderate margin on top of the local kWh prices.

Our preliminary analysis indicates that by opening up to third-party community charging, the TCO per kilometer for electric truck transportation can be further reduced by up to 30%. This calculation incorporates various factors, including the costs associated with truck acquisition and charging infrastructure installation, upgrading the grid, tolls, and maintenance. Moreover, we assume an electricity cost of 20 cents per kWh and an annual mileage of 50,000 kilometers.



Therefore, shared community charging hubs, coupled with intelligent reservation and management systems, can significantly reduce costs, resulting in a TCO that is considerably lower than that of comparable diesel trucks.

In addition, operational efficiency is a primary concern for fleet operators, who are seeking strategies to minimize driver waiting and charging times while maximizing charger and parking availability. In the highly competitive, low-margin transportation industry, time is precious and every hour lost translates into hundreds of Euros in additional cost.

Key operational questions of **fleet operators** include:



- ✓ What are my cost per kilometer, depending on prices for charging per kWh, both at the depot and en-route, and how predictable are prices for different times of the day?
- ✓ What kW charging power rate is required and what can be reliably expected? Is it possible to secure a guaranteed charging spot during legally required driver breaks?
- ✓ How can a fleet reserve charging sessions along the tour and how much flexibility would such a reservation provide to accommodate for deviations between the plan and execution of tours?

Fleet operators need to consider whether current routes need to be adjusted and how they can update their route planning to incorporate factors such as charger availability, reservation time windows, and external uncertainties such as traffic and weather that affect vehicle range. Looking to the future, it is also critical to consider the charging network and whether it will meet drivers' needs for rest infrastructure and convenience.

On the other hand, for **community charging providers**, which in the future will include depot and cross-dock operators, the focus shifts to maximizing utilization and revenue of their installed chargers.

Our data shows that private depot **charger utilization can drop to an average of 5-10%**, with expensive peaks during fleet turnaround cycles, when reducing the standing time of the truck is of essence.

Community, semi-public charging hubs, i.e., an opening of private depot and cross-dock chargers to third parties such as suppliers and neighbors, is a concept to increase infrastructure utilization and thereby significantly improve the TCO for infrastructure providers. Doing so requires an intelligent parking, reservation and charging management system. For example, dynamic third-party pricing and load balancing strategies can be implemented that take into account real-time grid electricity prices, local energy production (i.e. through photovoltaic or wind turbines), current charger utilization, and maximum power load constraints at the site.

Questions of [community charging providers](#), where charging operating systems like [K2 Mobility's PANION](#) software suite will be critical, include:



- ✓ How can I maximize my guaranteed infrastructure utilization through member contracts and subscriptions?
- ✓ How can I ensure that my members and customers get sufficient charging power with no wait times when they need it?
- ✓ How do I optimally assign charger capacity to satisfy the charging needs of a diverse fleet of electric trucks?
- ✓ How do I avoid prioritization conflicts among charging customers?
- ✓ What is the resulting average charger utilization and the number of chargers and peak loads required?
- ✓ How can I minimize energy cost through smart energy procurement, integration of battery storage in my energy mix and local energy production?
- ✓ How can I perform yield optimization with dynamic pricing based on demand prediction?
- ✓ How can I benefit from public subsidies and carbon emission benefits?
- ✓ What would a technical implementation look like in terms of charging protocols used and required mobile and web applications for user authentication and payment?
- ✓ What legal considerations must be addressed when selling electricity through chargers?

ELECTRIC VEHICLE ROUTE OPTIMIZATION IS NOT ENOUGH

The TCO benefits of a community charging hub

Overall, there are a number of questions currently facing fleet operators and community charging providers. In today's complex transportation networks, these questions extend to a variety of nodes, such as depots, production facilities, warehouse locations, ports and large retail outlets that can be used as community charging hubs, as previously described.

To optimize the routing through such complex transportation and charging networks, electric vehicle route optimization models, like the one offered through [Log-hub's](#) supply chain analytics platform, have been established. One of the primary considerations in these models is the battery capacity and route distance.

While for local distribution, allowing these trucks to charge at the start and end of each tour, for instance at the own depot, may be sufficient, for longer routes, en-route charging will be necessary, for example at a shared community charger at a logistics hub or at more expensive fast chargers along the highway.

The overall complexities and the numerous questions and challenges associated with a positive TCO for both fleet operators and community charging providers however demonstrate that a pure route optimization may not be sufficient.

A strategically shared community charging network is needed, combined with an intelligent parking, reservation, and charging management system.

We expect that large depots and cross-docks with large fleets of electric trucks will develop into major charging hubs, acting as [centers of gravity for charging in their neighborhoods](#).

As already highlighted, the introduction of third-party charging at private sites will significantly increase infrastructure utilization. This will allow depot and cross-dock operators to achieve significant reductions in TCO, accelerate return on investment, and realize economies of scale at their site.

[Academic research](#) is also investigating both electric vehicle routing problems and dynamic parking, reservation and charging management systems for shared electric vehicle charging.

In order to identify promising models and simulation experiments for practical implementation at scale, we conducted a review of the current state of research in both areas and highlight our key findings below.

The academic literature extensively addresses the [electric vehicle routing problem](#), which consists of finding optimal routes that minimize travel time, distance, and charging costs, considering both depot-based and en-route public charging.

From an operative perspective, typical variables accounted for are time-dependent electricity costs, waiting times, and delivery window constraints. The impact of variations in cargo weight, temperature, vehicle speed, traffic and weather conditions on a vehicle's energy consumption and range is being investigated, and collaborative models are emerging which propose the use of shared depots and joint charging stations.

To illustrate a promising example, Schoenberg and Dressler [7] present an algorithm to minimize the total travel time for EV routes, with a particular focus on waiting times at charging stations. They introduce a central database that estimates waiting times at charging stations based on current and historical utilization and planned stops of other vehicles. An adaptive routing and charging algorithm then adjusts routes, travel speeds and planned stops in a coordinated manner. A simulation was conducted involving 5,000 EVs traversing the German road and EV fast-charging station network.

The results demonstrate a [reduction](#) in the average [waiting time](#) at charging stations of [up to 97%](#).



To name another example, Pelletier et al. [8] propose a mathematical model that minimizes the total cost associated with the charging schedule of EVs at a private depot.

Their model incorporates time-dependent, variable electricity costs for recharging, as well as facilities-related fees, which depend on the maximum charging power drawn from the grid. The researchers consider a small number of slow and fast charging stations and introduce constraints based on realistic charging profiles that vary over time, contingent upon the state of charge (SoC), grid limitations, and considerations of battery degradation.



They identify an optimal charging schedule for a small fleet of medium-duty electric trucks and evaluate, whether vehicles should be charged simultaneously or sequentially after returning from their routes.

As previously introduced, dynamic parking, reservation, and charging management systems are fundamental to capture the full TCO potential with community charging hubs, and are also addressed in academia.

Key objectives include **maximizing revenue and utilization** for community charging providers and further **reducing waiting times** for fleet operators.

Research specifically examines the dynamic allocation of reservation slots, which must adapt to operational uncertainties such as varying arrival and charging times, fluctuating electricity rates, and gaps between peak and off-peak demand.

Moreover, studies in this field consider the diverse user requirements and utilities associated with charging costs, speed, and flexibility regarding the time of charging. This underscores the complexity of effectively managing such systems.

For instance, Bernal et al. [9] develop a mathematical model that maximizes the revenue from charging services. Revenue is calculated based on the sale of electricity to EVs, income from reservation fees, the cost of wholesale electricity purchased in the day-ahead market, and participation in real-time and reserve capacity markets.

The model considers various constraints, including a variety of charging rates, user choices regarding specific charge points, and decisions to make advance reservations, influenced by the cost of reservations and the likelihood of immediate service availability.

Their simulation for a small number of charging stations demonstrates that the reservation system outperforms the traditional first-come-first-served approach in terms of charging revenue and resource management.

Moreover, Cao et al. [10] present a management system for EV charging and station selection. The objective of their system is to minimize the duration of drivers' trips and their waiting time for charging through periodic reservation updates.

In their model, vehicles reserve charging spots via a central broker and continuously update their reservation status based on expected arrival times. They conduct a simulation involving electric vehicles in an urban setting.

The findings indicate that periodic reservation updates reduce the average charging waiting times and increase the number of fully charged EVs, particularly under conditions of traffic delay uncertainties.

They identify a reservation refresh rate of every 100 seconds as the best balance between charging performance and communication overhead.

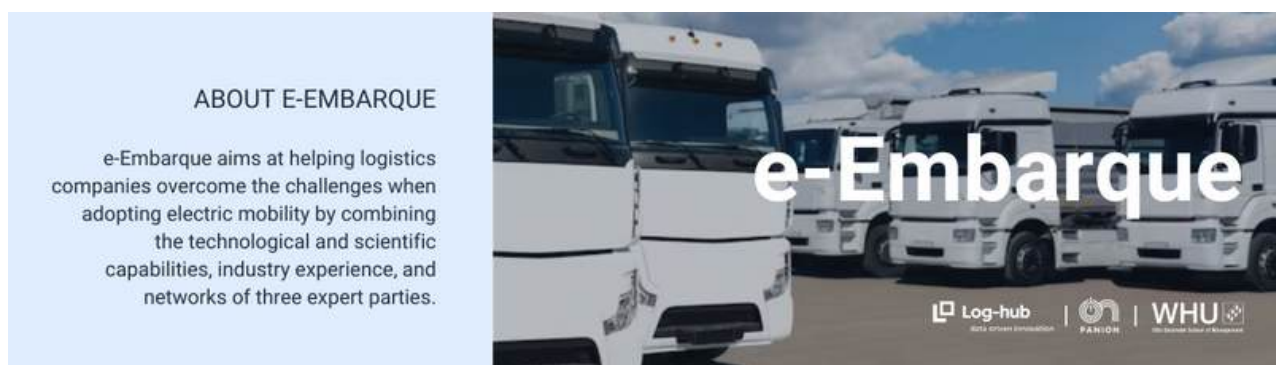


SO WHAT'S NEXT?

We expect community charging hubs, combined with dynamic charge planning, reservation and optimization systems, to be a key enabler for the cost-effective, large-scale operation of electric trucks. In the coming weeks, we will bring together the complementary capabilities of multiple market players, including fleet and logistics hub operators, to develop a business model that is both scientifically sound and profitable at scale, and to collectively develop pilot regions for future hubs.

Inspired to be part of this innovative movement?

We are eager to collaborate and move forward together. Please contact us and let us e-Embarque together.



Headquartered in Schindellegi, Switzerland, [Log-hub](https://log-hub.com/) is a leading provider of AI-based Supply Chain Apps and expert data, analytics, and AI services dedicated to supply chain optimization. With a focus on turning supply chain data into actionable insights, Log-hub empowers businesses to achieve operational excellence, cost reduction, and sustainability enhancement. For more information about Log-hub, its apps, and its services, please visit <https://log-hub.com/> or contact support@log-hub.com.



[K2 Mobility GmbH](https://k2mobility.com/) is a Software-as-a-Service company based in Potsdam, Germany, that provides dynamic and integrated charge-planning and energy management solutions to fleet operators with heavy electric vehicles. Its PANION software suite is being used by market leading logistics and public transportation companies around the world. For more information about K2 Mobility GmbH and its PANION software suite, please visit <https://k2mobility.com/> or contact info@k2mobility.com.



[WHU – Otto Beisheim School of Management](https://www.whu.edu/) is an internationally oriented, privately financed business school with university status located in Vallendar and Düsseldorf, Germany. WHU's high level of research competence is the result of a focus on three fundamental research principles: quality, internationality, and relevance for teaching and practice. For more information about WHU and the Chair of Logistics Management under Professor Stefan Spinler, please visit <https://www.whu.edu/>.

CONTRIBUTORS



Log-hub AG

Dirk Reich, Chairman of the Board of Directors
Jan Sigmund, Co-Founder and CEO



K2 Mobility (PANION)

Markus Kroeger, Founder, K2 and CEO, PANION
Ulrich Kalex, Co-Founder, K2 and CPO, PANION



WHU – Otto Beisheim School of Management

Stefan Spinler, Professor and Director, Institute for Logistics Management
Alexander Rose, Research Associate, Institute for Logistics Management

REFERENCES

- [1] German Council of Economic Experts: Spring Report (2024). <https://www.sachverstaendigenrat-wirtschaft.de/fruehjahrgutachten-2024.html>
- [2] National Centre for Charging Infrastructure (2024). <https://nationale-leitstelle.de/nutzfahrzeuge/>
- [3] Eurostat (2022): Road freight transport by distance class and type of transport (million vehicle-kilometres). 133,109 total in EU-27, thereof 57,780 below 300km, hence 43.4%. https://ec.europa.eu/eurostat/databrowser/view/road_go_ta_dc/default
- [4] Förderung für gewerblich genutzte Schnellladepunkte wird fortgesetzt (2024). <https://www.klimafreundliche-nutzfahrzeuge.de/foerderung-fuer-gewerblich-genutzte-schnellladepunkte-wird-fortgesetzt/>
- [5] National Centre for Charging Infrastructure (2024): User Journey. <https://nationale-leitstelle.de/einfach-e-lkw-laden-user-journey-und-neue-website-zur-ladeinfrastruktur-fuer-schwere-batterieelektrische-nutzfahrzeuge-veroeffentlicht/>
- [6] National Centre for Charging Infrastructure (2024): Charging at the Depot. <https://nationale-leitstelle.de/einfach-laden-am-depot-leitfaden-zum-aufbau-von-lkw-ladeinfrastruktur-an-betriebshoeefen-veroeffentlicht/>
- [7] Schoenberg, Sven; Dressler, Falko (2023): Reducing Waiting Times at Charging Stations With Adaptive Electric Vehicle Route Planning. In *IEEE Trans. Intell. Veh.* 8 (1), pp. 95–107. DOI: 10.1109/TIV.2022.3140894.
- [8] Pelletier, Samuel; Jabali, Ola; Laporte, Gilbert (2018): Charge scheduling for electric freight vehicles. In *Transportation Research Part B: Methodological* 115, pp. 246–269. DOI: 10.1016/j.trb.2018.07.010.
- [9] Bernal, Rodrigo; Olivares, Daniel; Negrete-Pincetic, Matias; Lorca, Álvaro (2020): Management of EV charging stations under advance reservations schemes in electricity markets. In *Sustainable Energy, Grids and Networks* 24, p. 100388. DOI: 10.1016/j.segan.2020.100388.
- [10] Cao, Yue; Wang, Tong; Kaiwartya, Omprakash; Min, Geyong; Ahmad, Naveed; Abdullah, Abdul Hanan (2018): An EV Charging Management System Concerning Drivers' Trip Duration and Mobility Uncertainty. In *IEEE Trans. Syst. Man Cybern, Syst.* 48 (4), pp. 596–607. DOI: 10.1109/TSMC.2016.2613600.