Sweden-China Bridge

Collaborative Academic Platform for the
Electrification of Transportation Systems

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BATTERY SWAPPING IN CHINA

REPORT FROM AN EXPLORATORY TRIP, 20-24 NOVEMBER 2023

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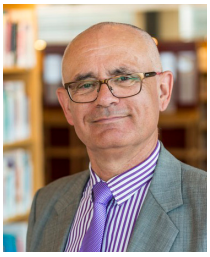

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SUMMARY

> *Of the ten largest manufacturers of electric heavy trucks, nine are Chinese! China is leading the electrification in the transportation sector, with Battery swapping for heavy trucks now becoming the dominant recharging infrastructure solution, expected to reach 70% in a few years*
>
> (Liu & Danilovic, 2021)

This meticulously arranged study tour offered a unique glimpse into Chinese electrification, focusing specifically on battery-swapping. Spanning from November 18 to November 25, 2023, the tour materialized through a robust and enduring collaboration between the Sweden-China Bridge project (SCB) – funded by Trafikverket (Swedish Transportation Administration) – led by Professor Mike Danilovic and Dr. Jasmine Lihua Liu from Halmstad and Lund University, respectively, and the esteemed Shanghai Dianji University.

The SCB project, with a history of exploring Chinese renewable energy since 2013 and the electrification of transportation since 2018, including a comprehensive study of battery-swapping, has amassed extensive knowledge. This enduring commitment has forged a vast network of industrial, business, and academic collaborations, affording a unique opportunity for on-the-ground observation and exchanging invaluable experiences. Collaborating with the regional logistics cluster Logistikia and VTI (Swedish National Road and Transport Research Institute), SCB has actively contributed to augmenting Sweden's understanding of battery-swapping as a complementary solution to cable charging.

The advocacy for battery-swapping arises from its recognized potential as a crucial enabler in scaling up the electrification of heavy transports, addressing significant obstacles faced by transportation companies, and grappling with challenges related to power capacity in local grids. Remarkably, from a Swedish standpoint, the apparent lack of awareness and discussion about battery-swapping on the national stage is noteworthy, especially given that public financing favors cable charging as the exclusive solution.

The explorative study program in China covered pivotal locations at the forefront of electrification in transportation. Participants gained a comprehensive understanding of the electrification landscape in China, with a specific emphasis on the status of battery-swapping as a concept and its organization and development within the Chinese context. The tour was an invaluable opportunity for participants to broaden and deepen their knowledge in this swiftly evolving field.

In short, we conclude the following experience from the trip:

Chinese electrification is significantly ahead of Europe in technological development and real-life implementation across all aspects of transport electrification. Several key observations highlight the notable lead China has in this domain:

- **Rapid Technological Advancements:** China demonstrates a remarkable pace in technology development and its swift implementation in practical scenarios. The transition from development to full-scale implementation is noteworthy, showcasing a breakneck speed.
- **Business-Driven Electrification:** While China's official climate goals provide a directional focus, the practical implementation of electrification, including battery-swapping, is predominantly driven by business considerations. Success in a business sense is a significant determinant for large-scale implementation.
- **Seamless Collaboration Between Academia and Industry:** A close and seamless collaboration between academia, research, and businesses contributes to rapid development, innovation, and practical implementation.
- **Wide Range of Battery-Swapping Solutions:** Battery-swapping solutions are available for all vehicles and trucks, with a notable emphasis on mining, construction/dumpster trucks, and trailer transportation.
- **Dominant Placement for Heavy Truck Batteries:** The prevalent battery-swapping solution for heavy trucks involves placing the battery behind the cabin on top of the chassis. Alternative solutions, such as side or below chassis swapping, are also being developed.
- **Grid Power Capacity Not a Constraint:** Unlike in Europe, grid power capacity is not considered a limiting factor in China. Companies prioritize business value, physical space utilization, and the time required for "recharging" through Battery-swapping.
- **Essential Role in Electrifying Heavy Trucks:** Battery-swapping emerges as a crucial solution for electrifying heavy electric trucks, dominating sales in China since 2022.
- **High-Speed Technical Development:** China exhibits high-speed technical development, with multiple generations of battery-swapping solutions already in the market.
- **Operational Efficiency and Effectiveness:** Chinese transportation companies prioritize the efficiency and effectiveness of operations when selecting electrification solutions, emphasizing practical considerations in their choices.

China's electrification landscape, particularly in battery-swapping, is a testament to its proactive and business-oriented approach, showcasing advanced technology, seamless collaboration, and a relentless pursuit of operational excellence.

ABOUT SWEDEN-CHINA BRIDGE

The Sweden-China Bridge initiative embarked on its research journey into the electrification of transportation systems in China in 2017-2018. This commitment was further reinforced in 2018 when a VIP team from the Swedish Transport Administration (Trafikverket, TRV) visited China to explore and gain insights into the country's electrification developments.

The research team contributing to the exploration of electrification in China includes Tech. lic., Arne Nåbo, Dr. Harrison John Bhatti, and Dr. Philip Linné are all affiliated with the Swedish National Road and Transport Research Institute (VTI). These researchers have been actively studying the progress, innovations, and dynamics of China's electrification efforts, providing valuable insights into the advancements and challenges within the transportation sector.

As facilitated by the Sweden-China Bridge project, the collaborative efforts between Swedish and Chinese stakeholders contribute to a deeper understanding of the developments in electrification. This collaboration allows for exchanging knowledge and experiences, fostering a comprehensive perspective on the ongoing evolution of electrified transportation in Sweden and China.

Sweden-China Bridge 1.0, 2020-2023

In 2020, the Sweden-China Bridge 1.0 project was initiated with a specific focus on delving deeper into the development of electrification in China's transportation sector. Throughout this exploration, the innovative and rapidly expanding battery-swapping solution emerged as a particularly intriguing aspect across various transportation systems. The project aimed to comprehensively understand and analyze the role and impact of battery-swapping as a dynamic and evolving technology in the context of China's electrification initiatives.

Sweden-China Bridge 2.0, 2023-2026

In 2023, the Sweden-China Bridge (SCB) launched a comprehensive three-year project, Sweden-China Bridge 2.0, with a strategic focus on adopting a systems approach to electrification and the intelligentization of transportation systems. This initiative reflects SCB's commitment to exploring and understanding the development and integration of various technologies across different system levels. The ultimate goal is to facilitate larger-scale electrification of vehicles within an integrated framework encompassing intelligent roads and smart cities throughout the entire value chain.

The Sweden-China Bridge project embraces three critical perspectives in its exploration of electrification in China:

1. **Holistic System Approach:** SCB is dedicated to adopting a holistic system approach, emphasizing a comprehensive understanding of how different technologies operate and interconnect across various system levels. This approach enables a nuanced examination of the complexities of achieving widespread electrification, considering the vehicles and the supporting infrastructure.
2. **Symbiotic Collaboration:** SCB recognizes the significance of symbiotic collaboration between decision-makers, institutions, regulators, and industry players. This perspective acknowledges the interconnected relationships and cooperative efforts required to drive renewable energy and transportation electrification advancements.
3. **Experimental Approach:** The project embraces an experimental approach to developing electrification in transport. This approach aligns with the dynamic and adaptive nature of the Chinese approach to renewable energy and transportation electrification, allowing for innovation, testing, and iterative progress.

The SCB project is exploratory, employing a step-by-step methodology to knowledge development. It spans diverse areas, including technology, business, and society, shedding light on the full spectrum of technologies involved in electrifying the transport system. This encompasses critical aspects such as minerals and batteries, intelligent vehicle systems, and their integration with intelligent roads and smart cities. The project aims to contribute to a comprehensive understanding of the evolving landscape of electrification in China and its implications for the broader global context.

LIST OF PUBLICATIONS

2021

1. Exploring Battery Swapping for Electric Vehicles in China 1.0, ISBN: 978-91-987011-0-4
2. Exploring Battery Swapping for Electric Heavy-Duty Vehicles in China 1.0, ISBN: 978-91-987011-1-1
3. Exploring Battery Technology for Electric Vehicles in China ISBN: 1.0.978-91-987011-2-8
4. Exploring Hydrogen Technology for Electric Vehicles in China 1.0, ISBN: 978-91-987011-3-5
5. Exploring Inductive Technology for Electric Vehicles in China 1.0, ISBN: 978-91-987011-4-2

2022

6. Multidimensional Readiness Index for Electrification of Transportation System in China, Norway, and Sweden. ISBN: 978-91-987011-5-9
7. A System Approach to Electrification of Transportation – An International Comparison, ISBN: 978-91-987011-6-6
8. Experiences of Battery Swapping for Electric Heavy Trucks From China, Summary of The Sweden-China Bridge Battery Swapping EHTs Webinar, June 2022, ISBN: 978-91-987011-8-0

2023

9. Utveckling av vätgas – Sverige i internationell jämförelse med Storbritannien, Spanien och Kina ISBN: 978-91-987011-7-3

10. Harrison, B., 2023. Sustainable Electromobility - A System Approach to Transformation of Transportation, Dissertation, Halmstad University.

2024

11. Nåbo, A, et.al, 2024. Battery-Swapping for Heavy Duty Vehicles - A Feasibility Study on Up-Scaling in Sweden, VTI, Statens väg- och transportforskningsinstitut/ Swedish National Road and Transport Research Institute (VTI) report 1199A, 2022/0471-8, Sweden

THE 2023 BATTERY-SWAPPING EXPLORATIVE TRIP-DELEGATION

The delegation comprised 17 individuals representing the Swedish transport and heavy-truck industry. This diverse group included professionals from transportation companies, transportation buyers, the heavy-truck industry, industrial networks, and research and innovation clusters from Sweden and Finland. The competencies within the group spanned a wide range, encompassing expertise in truck operation, battery technology, truck engineering, business and market analysis, and various other relevant fields.

The diversity of profiles and experiences within the delegation gave rise to dynamic discussions and the presentation of different perspectives. From truck operation to battery expertise, each member brought unique skills and insights to the table. This diversity enriched the learning experience during the study tour and facilitated a comprehensive exploration of Chinese advancements in battery-swapping and electrification.

The collaboration among individuals with distinct backgrounds fostered an environment where exciting discussions flourished and varied viewpoints were articulated. The different profiles within the group not only contributed to a multifaceted understanding of the subject matter but also encouraged innovative thinking and problem-solving. Overall, the diverse competencies and experiences within the delegation played a crucial role in ensuring a holistic and insightful exploration of the electrification landscape in China.

Program and visits

During our explorative study week, we embarked on a comprehensive program that delved into critical hotspots in Chinese electrification, explicitly focusing on battery-swapping. Our itinerary included immersive experiences covering various aspects such as observing battery-swapping in action, exploring different vehicles, visiting swapping stations, gaining insights into research and development of artificial intelligence and autonomous technologies, evaluating full-scale test road capabilities, and understanding manufacturing processes.

The program was packed with on-site visits, encompassing numerous meetings featuring presentations, discussions, and mutual Q&A sessions. Throughout the week, our hosts warmly welcomed the delegation at every stop, a gesture for which we express our sincere gratitude. We were deeply impressed by the openness and willingness of our hosts to share their experiences and practices in all the areas we explored, fostering a rich and collaborative learning environment.

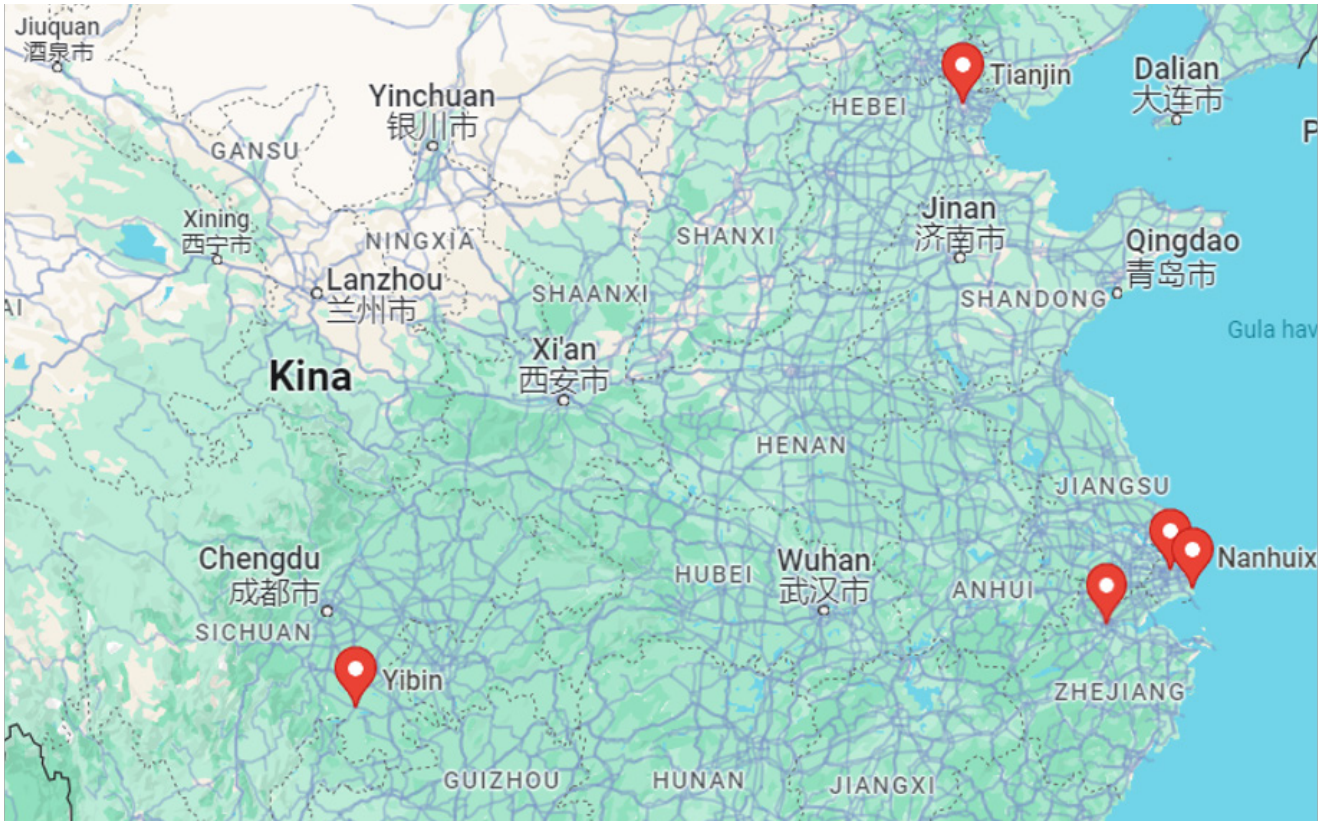
This successful trip was made possible due to the meticulous and extensive preparation led by Dr. Jasmine Lihua Liu and Prof. Mike Danilovic. Their dedication and thorough planning ensured the delegation had a well-rounded and insightful experience, contributing significantly to our understanding of Chinese advancements in electrification and battery-swapping. We sincerely appreciate their efforts in orchestrating this valuable study tour.

Exploring many places

Throughout the week, our exploration took us to diverse and significant locations in China, providing a comprehensive view of the advancements in electrification and battery-swapping. Our itinerary covered key cities and development hubs, including Shanghai, Lingang (a major strategic development area in China), Hangzhou, Yibin, Beijing, and Tianjin.

During our journey, we engaged in insightful visits to universities, research centers, cutting-edge test drive facilities, prominent vehicle manufacturers, leading battery manufacturers, developers, and manufacturers of battery-swapping systems. These immersive visits provided us with firsthand experiences and a deep understanding of the latest developments in intelligent heavy trucks.

The diverse locations and facilities we explored allowed us to witness the intricate web of research, development, and practical implementation within the electrification landscape in China. From academic institutions to state-of-the-art manufacturing facilities, our exploration provided a holistic view of the advancements in technology and infrastructure driving the rapid evolution of electrified transportation in China.



Five destinations in China visited by the team; Shanghai, Lingang, Hangzhou, Yibin, Beijing-Tianjin.

Explorative schedule of the week

SUN. 19 NOV.

Shanghai City

Walking tour in Shanghai

The initial impressions of Shanghai and the introduction to China were highly favorable and appreciated. The experience was described as stunning, particularly noting the prevalence of close to 100% electrified 2-wheelers and taxis in the city. This observation highlights China's significant strides in adopting electric vehicles for urban mobility, contributing to a cleaner and more sustainable transportation environment.

Shanghai, Bund in the night

MON. 20 NOV.

Lingang (Shanghai)

Shanghai Dianji University (SDJU) & Lingang municipality

President SDJU Siyi Gong, Director Yimin Bian.

The opening conference at Shanghai Dianji University (SDJU), the Chinese counterpart in the Sweden-China Bridge (SCB) project, was pivotal. It marked the initiation of collaborative efforts and provided a valuable platform for establishing contacts with research centers and companies in China. This conference created an opportunity for knowledge exchange, fostering meaningful connections between the Swedish and Chinese participants involved in the SCB project. Such interactions play a crucial role in facilitating collaborative research and promoting a deeper understanding of advancements in electrification and related technologies.

Shanghai DianJi University (SDJU) welcoming ceremony. President Professor Gong

Artificial Intelligent Center and Autonomous Driving Center

The presentation and visit to Lingang, an 800 km2 development area with intense activities, showcased a dynamic landscape of growth and innovation. The area was characterized by the influx of new companies, with notable developments, including Tesla's new factory. This visit provided firsthand insights into the bustling activities, ongoing projects, and the overall vibrancy of Lingang as a key hub for economic and industrial expansion. The presence of Tesla's new factory underscored the strategic importance of Lingang as a focal point for cutting-edge technological advancements and industrial development in the region.

Innovation Center – Future Vehicle

MON. 20 NOV.

Lingang (Shanghai)

Test Centers for autonomous driving and battery swapping

We visited three development nodes:

AI Center: With plans to house 30,000 to 50,000 people working on artificial intelligence (AI), this center represents a significant initiative in advancing AI technologies. The scale and focus on AI development highlight China's commitment to being a global AI research and innovation leader.

Autonomous Driving Center: The center dedicated to autonomous driving signifies a strategic focus on developing and advancing self-driving vehicle technologies. This reflects the broader global trend towards enhancing transportation through automation and intelligent systems.

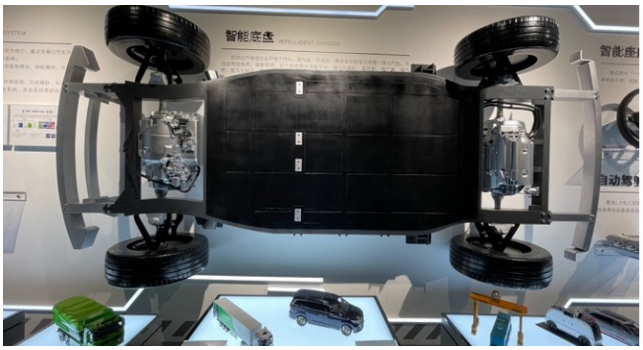
Test Range for Autonomous Driving and Battery-swapping: The test range is dedicated to assessing and refining autonomous driving technologies and battery-swapping systems. This type of infrastructure is crucial for the thorough testing and validation of innovations in the field of transportation, contributing to the overall progress of intelligent and electrified vehicles.

These centers are committed to cutting-edge technologies, including AI, autonomous driving, and battery-swapping. Such initiatives contribute significantly to the ongoing advancements in the transportation and technology sectors.

Battery-swapping practice
The mention of a test site for autonomous driving to the Port of Shanghai indicates a strategic focus on evaluating and advancing autonomous vehicle technologies within real-world scenarios. Testing autonomous driving capabilities in an environment that includes the route to the Port of Shanghai is particularly noteworthy, as it likely involves complex urban and industrial driving conditions.

This kind of test site serves multiple purposes:

Real-world Simulation: Testing autonomous vehicles in a real-world environment, especially towards a busy port, allows developers to simulate and address the challenges that autonomous systems may encounter in diverse and complex situations.



Intelligent chassis

Safety Verification: Evaluating autonomous driving capabilities in a controlled but realistic setting is crucial for ensuring the safety and reliability of these systems, both for passenger and cargo transport.

Logistics and Transportation Integration: Given the proximity to the Port of Shanghai, the test site may also involve assessing the integration of autonomous vehicles into the broader logistics and transportation ecosystem, providing insights into potential efficiency improvements and operational optimizations.

This initiative aligns with the global trend of integrating autonomous technologies into various sectors, with a particular emphasis on applications in transportation and logistics for increased efficiency, safety, and sustainability.

Aulton, 3rd party battery-swapping system developer

Aulton test and development for swapping from the side (battery between axles).

MON.
20
NOV.

Lingang (Shanghai)

Seminar from SPIC, world's largest producer of green power

The presentation from SPIC (State Power Investment Corporation) detailing the development of the first swapping systems is a significant insight into the evolution of battery-swapping technology in China. With 500 operational stations currently in place, each station servicing an average of 40 vehicles, this highlights the scalability and widespread adoption of battery-swapping infrastructure.

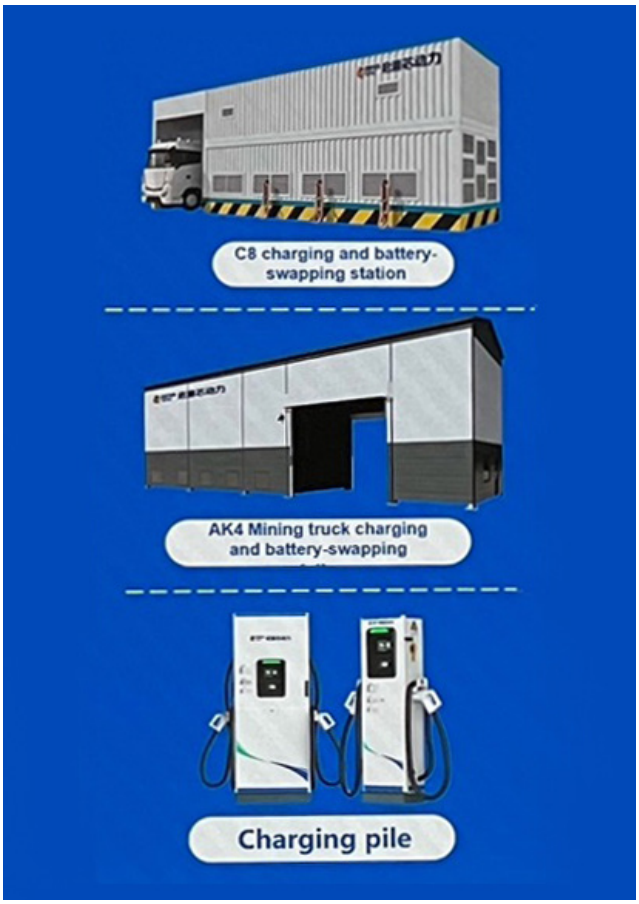
Key takeaways from SPIC's presentation include:

Pioneering Role: SPIC's role as an early developer of battery-swapping systems underscores its pioneering efforts in advancing electric vehicle infrastructure.

Operational Scale: The large number of operational stations signifies the extensive deployment of battery-swapping technology across the region, contributing to the electrification of transportation at a broad scale.

Vehicle-Swapping Ratio: The average of 40 vehicles per station provides insight into the efficiency and capacity of the battery-swapping infrastructure, showcasing its ability to cater to a considerable number of electric vehicles.

This information reflects the practical implementation and success of battery-swapping systems, highlighting their role in supporting the widespread adoption of electric vehicles and contributing to the overall electrification of transportation in China.



SPIC Battery-swapping solutions

TUES.
21
NOV.

Hangzhou

Geely, Farizon, meet and study BS station in operations

Test driving

The visit to the swapping station developed and operated by Geely provides valuable insights into the practical application of battery-swapping technology in the context of concrete trucks in the concrete industry. Some key points from this visit and meeting with Geely include:

Operational Efficiency: The station's ability to support 20+ concrete trucks in the concrete industry showcases the adaptability of battery-swapping technology for specific industrial applications, contributing to the electrification of heavy-duty vehicles.

Performance Metrics: The station's impressive capacity, supplied with 2.5MW, performing a maximum of 168 swaps per day with 7 batteries, emphasizes the efficiency and reliability of the swapping infrastructure. The quick swapping time of 3 minutes further enhances operational efficiency.

Flexibility and Mobility: The station's capability to be relocated in 48 hours highlights the flexibility of battery-swapping infrastructure, allowing for strategic placement based on operational needs. The compact footprint of 60m2 is another notable feature.

Discussion with Geely: The meeting with Geely, discussing technical development, marketing strategies, and differences in the Chinese and Swedish transportation markets, provides a comprehensive understanding of the factors influencing the adoption and adaptation of electrification solutions.

Farizon Homtruck: The presentation of the Farizon Homtruck, with features such as long-haul transport capabilities, L4 autonomous ability, built-in battery-swapping as a standard solution, and a well-equipped cabin, offers a glimpse into the future of electric heavy-duty vehicles. The timeline for market availability by 2025 indicates ongoing advancements in this sector.

Cable Truck Development: The mention of Farizon developing a cable truck for closed environment operations demonstrates the diversity in the application of electric vehicles, catering to specific operational requirements.

This visit and meeting contribute to a deeper understanding of the technical aspects, market strategies, and upcoming developments in the Chinese electric transportation sector, particularly in the heavy-duty and industrial vehicle segments.

This stand-alone EV-platform is a product of Zhi Li Wu Lian and CATL.

WED. 22 NOV.

Yibin

Visit at CATL battery manufacturing

The visit to CATL's battery manufacturing facility is a significant experience, providing a firsthand look at the cutting-edge technology and innovations in electric vehicle (EV) battery production. Some key points from the visit include:

Global Leadership: CATL's achievement of being ranked number 1 globally in EV battery production for six consecutive years (as of 2022) reflects its leadership and excellence in the electric vehicle battery industry.

Exhibition Area: The visit to the exhibition area offers insights into CATL's product portfolio, showcasing the diversity and advancements in EV battery technology.

Integration Research and Development: The focus on integration research and technical development, including battery research, highlights CATL's commitment to continuous improvement and innovation in electric vehicle batteries.

"In 2022 CATL was ranked n:o 1 globally in EV battery production for 6 consecutive years"

https://www.catl.com/en/about/profile/

THUR.
23
NOV.

Yibin

Exploring the Prof Ouyang Minggao Academician Workstation, Sichuan New Energy Vehicle Innovation Center

Visit at Zhi Li Wu Lian

The mention of Zhi Li Wu Lian's research and development activities in batteries, vehicle mounting fixtures, swapping robots, and two generations of swapping stations illustrates a holistic and collaborative approach to advancing battery technology and its integration into the battery-swapping system. The collaboration with several Chinese universities further underscores the commitment to leveraging collective expertise and knowledge in pushing the boundaries of electric vehicle battery technology.

Key points from the visit to Zhi Li Wu Lian:

Research Collaboration: Zhi Li Wu Lian's collaboration with Chinese universities in battery technology research signifies a concerted effort to harness academic expertise for advancements in battery science and engineering.

Integrated Batteries: The integration of batteries into the design of the battery-swapping system showcases a comprehensive approach, ensuring that both the energy storage technology and the infrastructure supporting it are developed in tandem.

Contribution to Industry Understanding: This visit contributes to a broader understanding of the technological landscape within the electric vehicle battery industry. It sheds light on how key players like Zhi Li Wu Lian are actively involved in research, development, and collaborative efforts to shape the future of electric mobility.

By exploring these technological advancements, the visit provides valuable insights into the intricate web of research, innovation, and collaboration that propels the electric vehicle industry forward, aligning with the global trajectory towards sustainable and advanced transportation solutions.

Zhi Li Wu Lian, Factory, Swapping Test Sites and Swapping Operational Site

The visit to Zhi Li Wu Lian's manufacturing and test site, particularly exploring the new generation with a linear robot for battery-swapping, offers valuable insights into the evolving technologies within the electric vehicle (EV) infrastructure.

Key points from this visit include:

Advanced Swapping Technology: Exploring the new generation featuring a linear robot highlights advancements in battery-swapping technology. Using a linear robot emphasizes efficiency and speed in the swapping process.

Test Driving Battery-swapping-based Heavy Truck

Manufacturing and Testing: The visit to Zhi Li Wu Lian's manufacturing and test site provided a first-hand look at the production processes and quality assurance measures, showcasing the company's commitment to delivering reliable and high-performance battery-swapping solutions.

Operational Swapping Station: Visiting Zhi Li Wu Lian's operational swapping station offers practical insights into how their technology functions in real-world scenarios. Observing the station in action provides a better understanding of the user experience, efficiency, and reliability of the battery-swapping process.

This visit contributes to a comprehensive understanding of the advancements in battery-swapping technology, emphasizing the manufacturing and testing aspects and the practical implementation in operational settings. It showcases the role of companies like Zhi Li Wu Lian in driving innovation within the electric vehicle ecosystem, focusing on enhancing the user experience and promoting the adoption of sustainable transportation solutions.

FRI.
24
NOV.

Tianjin (Beijing area)

DeepWay Trucks and Battery-swapping Station, Development, and Test Drive Area

Studying and testing the newly developed Intelligent truck by DeepWay provides significant insights into the latest advancements in autonomous driving and electric truck technology. Key points from this experience include:

Market Availability: The confirmation that the DeepWay Intelligent truck is already on the market underscores the company's progress in bringing advanced electric vehicles to commercial availability.

Real Traffic Tests: The announcement of real traffic tests starting in December 2023, specifically focusing on autonomous Level 4 (L4) capabilities, showcases DeepWay's commitment to pushing the boundaries of self-driving technology. The Level 4 autonomy, with human monitoring, reflects a significant step toward fully autonomous driving.

StandardBattery-swapping Solution: Adopting battery-swapping as a standard solution in the DeepWay Intelligent truck, with the battery placed between

axles and the swapping mechanism from below, aligns with the industry trend towards flexible and efficient energy replenishment methods for electric vehicles.

This experience contributes to a deeper understanding of the integration of autonomy, electrification, and innovative charging solutions in the transportation sector. DeepWay's developments exemplify the ongoing advancements in creating intelligent and sustainable solutions for the future of mobility.

REFLECTIONS ON THE CHINESE ELECTRIFICATION

From 2-wheelers to taxis and trucks

A notable shift towards electric mobility is evident in Shanghai, with all mopeds, scooters, and most taxis now being electric. This widespread adoption has resulted in silent and nearly emission-free traffic within the city. However, heavy trucks observed in the urban and highway settings still predominantly rely on fossil-based fuels.

During our exploration, we observed a positive trend in the electrification of trucks, particularly in construction areas. Electric trucks, often equipped with battery-swapping capabilities, were prevalent in these regions visited during the trip. The impression gained is that the electrification of heavy trucks is emerging as concentrated clusters, with significant concentrations of electric trucks, rather than being evenly distributed across the country.

This localized approach suggests that certain regions or clusters are leading the way in adopting electric heavy trucks, possibly driven by specific industries or favorable conditions. The prevalence of battery-swapping technology in these regions reflects a strategic approach to address charging infrastructure challenges and optimize electric trucks' operational efficiency.

Overall, the observed trends indicate a dynamic landscape in the electrification of heavy trucks in China, with distinct clusters showcasing advancements and serving as potential models for broader adoption across the country.

Speed in Innovation and Application

The companies we visited during the trip demonstrated an impressive pace of development, showcasing agility and innovation. DeepWay, founded in December 2020, has made remarkable strides by introducing several hundred new intelligent electric trucks to the market within a relatively short timeframe.

What stands out is the accelerated pace of innovation, where new prototypes are developed and tested within months. This approach contrasts with the traditional sequential process, indicating a seamless and dynamic methodology. The emphasis on speed is evident, prioritizing bringing new products to the market swiftly and addressing any imperfections or faults iteratively as they arise.

This approach reflects a mindset that values rapid progress and adaptability over achieving perfection initially. The willingness to iterate and correct faults as products are introduced to the market underscores a commitment to continuous improvement and responsiveness to evolving market demands. The observed speed in development suggests a proactive and dynamic strategy to stay at the forefront of the rapidly evolving landscape of intelligent electric trucks.

Integration Between Research and Companies

The integration between research and companies in China is characterized by frequent, fast, and close cooperation, often displaying a symbiotic relationship. While the intricate interplay between politics, institutions, industry, companies, and academia may be complex for a foreign observer, the evident collaboration is instrumental in the rapid progression of Chinese electrification. A notable example of this synergistic approach was observed during our visit to the Sichuan New Energy Vehicle Innovation Center and Zhi Li Wu Lian.

Led by Professor Minggao, who holds a Ph.D. from Denmark, the institution serves as an incubator for numerous companies that actively collaborate and maintain strong connections with the center. This collaborative model reflects a cohesive ecosystem of research, innovation, and commercialization. The close cooperation among various stakeholders, including academia and industry players, is a pivotal factor contributing to the accelerated pace of Chinese electrification.

The observed speed of progress in Chinese electrification is attributed, in part, to the seamless collaboration between different actors in the ecosystem. The symbiotic relationships between research institutions and companies foster an environment where ideas are rapidly incubated, tested, and brought to market. This collaborative spirit is a critical driver in China's ability to swiftly adapt to the evolving landscape of electrified transportation and emerge as a global leader in this domain.

Vehicle standard

Compared to premium brands like Scania and Volvo, Chinese trucks may be perceived as more straightforward. From the perspective of a Swedish driver, they may have lower standards in areas such as suspension and the quality of materials. The preferences of Swedish drivers might not align with this version of trucks, given the higher standards they are accustomed to from premium brands. It's crucial to note that this perception does not imply a lack of quality in Chinese trucks.

Chinese manufacturers can produce trucks with higher standards if requested. Cost considerations often influence the choice of a more basic or standard version. It's a strategic decision to cater to different market segments and price points. In markets where cost-effectiveness is a priority, manufacturers may offer more straightforward configurations, while in markets where premium features are valued, they can provide trucks with enhanced specifications.

Therefore, the perception of Chinese trucks being more straightforward or of lower standards should be understood in the context of varying market demands and cost considerations rather than indicating an inherent lack of quality. Chinese manufacturers can produce trucks that meet diverse quality standards based on customer requirements and market preferences.

Autonomous Driving

The electrification of transportation in China is intricately linked to the broader trends of digitalization and the advancement of autonomous driving technologies. This integration is driven by various factors, including the considerable cost associated with truck drivers, even in developing economies with lower salaries.

In both the Chinese and European markets, there is an increasing demand for drivers, particularly for long-haul transport. To address the needs of long-haul drivers, modern trucks are equipped with amenities for increased comfort, including features like showers, washing machines, and toilets. These enhancements aim to improve the working conditions for drivers who spend extended periods on the road.

Autonomous driving technology, especially at level L4, is anticipated to become a crucial selling feature for modern trucks in 2024. The development of autonomous driving capabilities is seen as a solution to address the challenges related to the shortage of drivers, enhance safety, and increase overall efficiency in the transportation industry.

The industry aims to create a more sustainable, efficient, and technologically advanced transportation ecosystem by combining electrification with digitalization and autonomous driving. These developments represent a holistic approach to addressing various challenges in the trucking sector, from reducing environmental impact through electrification to improving operational efficiency and addressing the shortage of drivers through autonomous technologies.

A battery swapping heavy truck with the battery mountedbehind the cabin.

BATTERY DEVELOPMENT AND BATTERY-SWAPPING, LESSONS LEARNED

Battery development

The electric vehicle industry is marked by numerous manufacturers producing various electric vehicles, including passenger cars and trucks. However, when it comes to battery suppliers, the landscape is more consolidated, with a few dominant players. CATL (Contemporary Amperex Technology Co. Limited), a world-leading battery manufacturer, holds a prominent position, representing approximately one-fifth of all vehicle brands. This includes heavy trucks, passenger cars, and associations with major automakers such as VW and Tesla.

Research on the electric vehicle sector is intensive and concentrated on key areas crucial for battery technology. These areas include energy density (kWh/kg), capacity (kW), battery maintenance, cost considerations, and safety protocols. The first generation of batteries primarily relies on Silicon, offering a theoretical maximum energy density of around 400Wh/kg.

The ongoing research directs attention toward next-generation batteries that might be sodium (Na)-based, albeit with lower energy density, or iron (Fe)-based, with a substantially higher energy density of around 600Wh/kg. This exploration into advanced battery technologies aims to improve overall performance, increase energy storage capacity, and enhance the efficiency of electric vehicles.

Given the strategic importance of batteries in the electric vehicle ecosystem, battery manufacturers, including major players like CATL, hold a pole position. Their role extends beyond being suppliers; they play a critical role in shaping the future of electric mobility by controlling a key and strategic component of electric vehicles. The competition and advancements in battery technology are pivotal factors influencing the trajectory of the entire electric vehicle industry.

Battery swapping

Battery-swapping has rapidly gained traction in the Chinese market, establishing itself as a crucial and complementary technology for recharging heavy trucks. Despite being relatively new and having been on the market for about five years, battery-swapping is well-established in China, with thousands of vehicles in operation and multiple generations of swapping stations offering different solutions.

As of November 2023, China has 3,394 heavy truck battery-swapping stations, showcasing the scalability and flexibility of this technology. SPIC (State Power Investment Corporation), a pioneer in its development, has more than 21,000 vehicles with battery-swapping capability on the market and over 500 swapping stations with diverse designs.

Battery-swapping-based trucks command about 50% of China's electric heavy truck market, underscoring this technology's proven and robust nature. This approach is particularly advantageous regarding scalability and flexibility, with a minimal footprint compared to cable charging.

The market for electric trucks in China is rapidly expanding, with a significant portion designed for battery-swapping. In 2022, 48.8% of electric trucks sold were swap-capable, and this is expected to rise to around 75% in the coming years. The sales of battery-swapping heavy trucks have seen remarkable growth, with 7,952 units sold from January to August 2023, marking a year-on-year increase of 26.64%.

The dominant solution for battery-swapping involves mounting the battery behind the cabin, offering a simple technical solution for both vehicles and swapping stations. While this approach may intrude on load space, it has proven to be a verified and robust solution, particularly in challenging environments. Despite the potential concerns about the high mounting affecting the center of gravity, no such adverse effects have been reported.

Manufacturers are exploring alternative solutions, such as mounting batteries within the chassis frame, similar to traditional cable-charged vehicles. Different swapping methods are being developed, including from below and from the side. However, the current dominant solution remains the battery placement behind the cabin, swapping upwards. The rapid adoption and diverse approaches in the battery-swapping landscape underscore the dynamic evolution of this technology within the Chinese electric truck market.

Applications

Battery swapping technology is not limited to specific types of vehicles, as it has found applications across various sectors, including two-wheelers, passenger cars, boats, and heavy machinery. This technology has diverse applications in heavy trucks, primarily focusing on construction (dump trucks, concrete trucks) and mining operations characterized by short distances and high delivery frequency.

The development of battery-swapping stations for heavy trucks has evolved through three distinct phases:

1. **Stand-alone:** In this phase, a single swapping station caters to multiple local trucks operating in the same area. Trucks in the vicinity utilize the same station, and this model can operate independently without widespread market penetration. Typically, with around 20 trucks using the station, the utilization rate reaches a break-even point.

Swapping station DeepWay trucks, swapping from below

2. **Local grid:** This phase involves the establishment of several swapping stations within a specific area. Trucks in the region can choose to use any of these stations to swap batteries, creating a local grid of interconnected swapping facilities.

3. **Connecting cities: T**he latest phase focuses on deploying swapping stations along highways, enabling trucks to cover longer distances between remote destinations. This development is particularly beneficial for heavy trucks engaged in inter-city transportation.

In addition to battery-swapping, it's noteworthy that several battery-swapping trucks were observed parked and charging via cable at traditional charging stations. This dual approach allows for flexibility and ensures that heavy trucks can be charged conventionally when necessary.

The multi-phase evolution of battery-swapping stations reflects the adaptability and scalability of this technology, catering to the unique operational needs of heavy trucks in different contexts, from localized applications to longer-haul transportation along highways.

The Chinese business case versus a Swedish/European perspective

China's commitment to reducing CO_2 emissions has set a clear direction towards electrification, aligning with national goals. The development of electrification in China is primarily business-driven, with transportation companies opting for battery-swapping trucks when they prove to be more economically viable, especially compared to diesel alternatives. The potential for better revenue and cost-effectiveness often influences companies' decision-making process.

In this business-driven model, swapping station operators derive their primary earnings from the energy sold during battery-swapping. This approach supports the sustainability goals and ensures a revenue stream for station operators.

Contrastingly, the grid-capacity problems in Sweden, where insufficient power is emerging as a bottleneck in electrification efforts, are a non-issue in China. In discussions with several companies, the limitations in power for charging were different from the Chinese context. China's infrastructure and power capacity are more accommodating, facilitating the widespread adoption of electric vehicles, including those utilizing battery-swapping technology.

Moreover, while grid capacity challenges might not be a current concern in China, developing the "vehicle to grid" (V2G) function is actively underway. This includes applications not only for traditional charging but also for battery-swapping stations. The V2G function holds the potential to enable a bidirectional flow of energy between vehicles and the grid, enhancing the overall flexibility and sustainability of the electric transportation ecosystem.

The differences in the electrification landscape between China and Sweden highlight the role of infrastructure and national policies in shaping the adoption and success of electric vehicle technologies.

Standardization

Standardization in electrification is a significant focus in China and Europe, emphasizing the importance of establishing standards, norms, and practices across the industry. In China, a dedicated national organization promotes standardization in battery-swapping, reflecting the commitment to ensuring consistency and interoperability within the sector.

While standardization is encouraged, companies in both regions can choose whether to adhere to established standards or develop proprietary solutions. Unlike some industries where standards are mandatory, there are currently no regulations regarding electrification standards. This approach allows for innovation and diverse solutions within the framework of established norms.

A long tradition of dialogue within Chinese organizations facilitates China's emphasis on standardization. This tradition contributes to a collaborative environment that aids standardization, fostering communication and cooperation among industry players.

China has made strides in establishing standards for frame-mounted batteries, with one officially recognized as a national standard. Zhi Li Wu Lian's involvement in manufacturing batteries and providing adapters for different standards underscores the adaptability required in a rapidly evolving industry.

In the context of frame-mounted batteries, there are currently two standards in China, one of which has been accepted as a national standard. Zhi Li Wu Lian, a major manufacturer, plays a significant role in this domain and provides an "adapter" for situations where the battery and vehicle adhere to different standards. This adaptability reflects an effort to promote compatibility and ease of integration.

However, in the case of batteries mounted between axles, there has yet to be a universally accepted standard. Companies developing this concept have chosen to pursue individualized solutions, emphasizing the evolution and diversity of battery technology and its application in electrified transportation. The collaborative dialogue and standards-setting efforts aim to balance innovation with the need for consistent practices in the rapidly advancing field of electrification.

However, the absence of a universally accepted standard for batteries mounted between axles reflects the ongoing evolution of standards to accommodate emerging technologies. Pioneering companies in China are taking individualized approaches in this aspect, showcasing the adaptability and innovation inherent in the Chinese electrification landscape.

This shared commitment to standardization, coupled with a flexible and collaborative approach, highlights the global nature of the electrification movement and the importance of harmonized efforts to drive sustainable and innovative solutions across regions.

The Chinese Perspectives on Electrification of Transport

The Chinese perspective on electrification, marked by proactive national goals and business-oriented strategies, contrasts the challenges and considerations in Sweden and Europe.

Key points from this perspective include:

Standardization Initiatives: China's dedicated national battery-swapping Organization actively promotes standardization, creating a framework for interoperability. Unlike Europe, the absence of mandatory regulations allows companies in China to choose their level of adherence, offering flexibility within a standardized context.

Frame-mounted Battery Standards: China currently boasts two standards for frame-mounted batteries, with one being nationally accepted. Zhi Li Wu Lian's role in producing adapters to accommodate different standards reflects a pragmatic approach to address variations in battery and vehicle configurations.

Batteries Between Axles: The absence of a universally accepted standard for batteries mounted between axles underscores the ongoing evolution of standards in response to emerging technologies. Companies in China are presently adopting individual solutions for this specific application.

National Goals and Business Strategy: China's electrification drive is not only guided by national goals to reduce CO_2 emissions but is also business-driven. Transportation companies strategically invest in battery-swapping trucks, considering environmental and financial factors.

Grid Capacity and "Vehicle-to-Grid" Development: Unlike Sweden's grid-capacity challenges, China does not express concerns about power limitations for charging. Moreover, the active development of the "vehicle-to-grid" function reinforces China's commitment to exploring innovative solutions in the electrification landscape.

Understanding these distinctions between Chinese and European perspectives is crucial for fostering international collaboration and drawing insights from diverse approaches. Exchanging ideas and experiences can contribute significantly to the global transition toward sustainable and efficient transportation solutions.

Standardization

This commitment to standardization in China aligns with Europe's priorities in the electrification domain. Notably, a dedicated national battery-swapping organization in China actively driving standardization reflects a shared emphasis on creating a cohesive framework for the evolving industry.

In China, the absence of mandatory regulations provides companies with the flexibility to decide whether to adopt established standards. This approach encourages collaboration and creates a more dynamic and responsive development process. The tradition of open dialogue within Chinese organizations further facilitates standardization, fostering cooperation and shared goals.

FINAL WORDS

Significantly, the awareness of battery-swapping in Sweden and Europe remains remarkably low despite its standing as the dominant solution in Chinese electrification, with a substantial lead over Europe. We contend that the primary factor contributing to this discrepancy is the reluctance of European manufacturers to discuss and test the concept openly within their home market. Additionally, a bias in public funding favoring cable charging further impedes exploring and validating the battery-swapping concept.

There needs to be more operational battery-swapping stations or trucks in Europe, presenting a notable challenge in thoroughly evaluating this solution within our distinct market conditions. It's crucial to note that the lack of interest is absent from transportation companies or buyers; quite the opposite, there is a keen eagerness to adopt such solutions as soon as they become available.

The consortium, comprising Sweden China Bridge, VTI, and Logistikia, is committed to advancing efforts to place battery-swapping prominently on the Swedish national agenda. Our collective aim is to disseminate knowledge and generate interest, with the immediate target being the initiation of testing a battery-swapping system in the Swedish market. This ongoing endeavor is poised to contribute significantly to the broader adoption and understanding of this innovative approach in electrified transportation.

READ ABOUT SWEDEN-CHINA BRIDGE

We invite you to explore the Halmstad University homepage for comprehensive details on the Sweden-China Bridge project and to access all our publications. You'll find in-depth information about the project's goals, accomplishments, and ongoing initiatives there. The website offers the convenience of downloading all our publications, providing a thorough understanding of the strides made and collaborative endeavors in transportation system electrification. Feel free to navigate through our homepage to delve into a wealth of knowledge and stay abreast of the latest developments in this dynamic and impactful project.

https://www.hh.se/english/research/our-research/research-at-the-school-of-business-innovation-and-sustainability/research-projects-at-the-school-of-business-innovation-and-sustainability/sweden-china-bridge.html

BUILDING BRIDGES

The Sweden-China Bridge is a dynamic platform dedicated to advancing knowledge and nurturing collaboration within the ever-evolving landscape of transportation system electrification. Through thoughtfully curated seminars and publications, we actively facilitate the generation and sharing of valuable insights.

This exploratory journey is a testament to our proficiency in bridging Swedish and European stakeholders with their counterparts in China, a proficiency honed over years of dedicated efforts.

Suppose you are eager to traverse this metaphorical bridge, delving into the latest advancements in China and forging robust connections with academic and industrial partners in the region. In that case, we invite you to contact us. Let's explore the myriad opportunities awaiting you as we embark on this journey together.