Steel E-Motive
Shaping the Future of Sustainable Transportation
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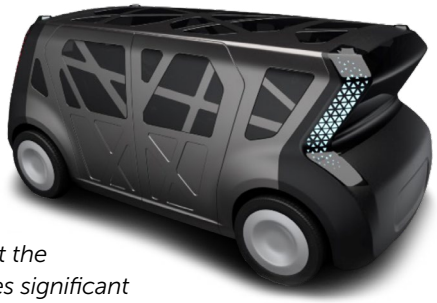
Technical Microstudies Highlighting Design and Performance Innovations for Steel E-Motive

Steel E-Motive: Autonomous Ride Sharing Concepts Deliver Comfort, Accessibility and Functionality



Introduction

Urbanization and Net Zero Emissions targets are key contributors of the transportation shift to mobility on demand in densely populated urban environments. It's here that the mobility industry anticipates significant growth in ride sharing, with emphasis on the use of autonomous vehicle technologies and electrification to achieve that goal.

WorldAutoSteel's Steel E-Motive program developed two autonomous ride sharing concepts: SEM1, a four-seat urban passenger vehicle, and a larger SEM2 variant, seating up to six passengers. Both can operate in mixed mode traffic, with a maximum speed of 130km per hour. These concepts feature expansive application of modern high-strength steels designs to provide appealing experiences for all users.

Fully autonomous Mobility-as-a-Service (MaaS) vehicles mark a significant shift in urban transport modes. Despite their advantages and benefits, they will need to compete and be compatible with public transportation, privately owned and manually driven vehicles. To encourage adoption and generate demand for MaaS, these vehicles must offer competitive levels of comfort, convenience, accessibility and safety for passengers.

The term **passenger comfort** refers to minimizing the discomforts passengers may experience throughout their journey. These can include physical sensations such as vibrations and motion caused by road conditions and vehicle manoeuvres, as well as auditory disturbances such as tire noise, bumps, wind, electric motor sounds, squeaks, rattles and inconsistent temperature or humidity. Interior design elements – such as space, layout and ergonomics – also play a crucial role in enhancing comfort.

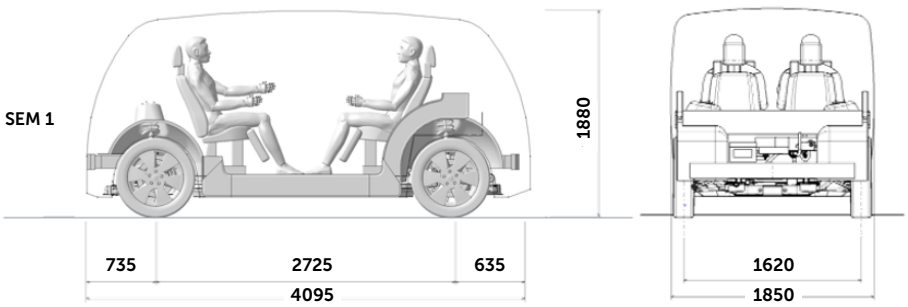
Convenience relates to how easily users can access and use the service. Users will expect fast, dependable and on-demand service that enables target destinations to be achieved, while integrating smoothly with existing transport systems like trains, buses and ferries. These vehicles must be capable of operating reliably across a wide range of environments – from dense urban centres to remote areas.

Design considerations must enhance **accessibility** to accommodate a diverse user base, enabling mobility for infants and children, the elderly and people with disabilities, including visual impairments. Since these vehicles are autonomous and lack a human driver, support for passengers with special needs must be thoughtfully integrated into the design.

Finally, consumers must be confident in the **safety** of these vehicles and services, to drive their growth in urban settings. WorldAutoSteel's Steel E-Motive program demonstrates autonomous ride-sharing vehicle concept designs which address these requirements by applying the latest Advanced High-Strength Steel grades and manufacturing processes.

Steel Body Construction Enables Compact, Space-Efficient Vehicle Design

Vehicles operating in congested urban areas benefit from a compact design and good manoeuvrability. The objective of the Steel E-Motive program was to create a vehicle that feels small on the outside, large on the inside, enabled by steel's efficient packaging and strength. The SEM1 vehicle has an overall length of 4.095m and 1.85m width – positioned between a typical European B- and C-segment passenger vehicle. Short front and rear overhang distances result in a greater proportion of available cabin space. Despite its compact dimensions, the vehicle features an open, spacious interior, facilitated by a carriage train inward-facing seating configuration. The front occupants are seated rear-facing, in a space usually occupied by an instrument panel in a conventional vehicle – a feature and configuration unique to fully autonomous passenger cars. This creates an open, accessible space between the front- and rear-seated occupants. The Steel E-Motive vehicle features scissor side doors, the kinematics of which enable a large (1.0m) door opening aperture, facilitating accessibility for wheelchairs and their users.



SEM1 Dimension	mm
Overall vehicle length	4095
Overall vehicle width	1850
Overall height	1880
Wheelbase	2725
Front track	1620
Front overhang	725
Rear overhang	635

Figure 1. Steel E-Motive SEM1 vehicle dimensions

The conventional Body-in-White (BIW) B-pillar structures are located within the side doors, further complementing the door- opening aperture and accessibility. The high vehicle roof line combines with the semi-glazed roof panel and open seating plan to create a spacious, airy feel to the Steel E-Motive interior, accentuating the perception and experience of the fully autonomous MaaS vehicle. 3D Virtual Reality tools were deployed to assist the development and evaluation of the vehicle layout and interior. **Figure 2** shows 2D images from the 3D visualisation of the Steel E-Motive interior from a seated occupant perspective.

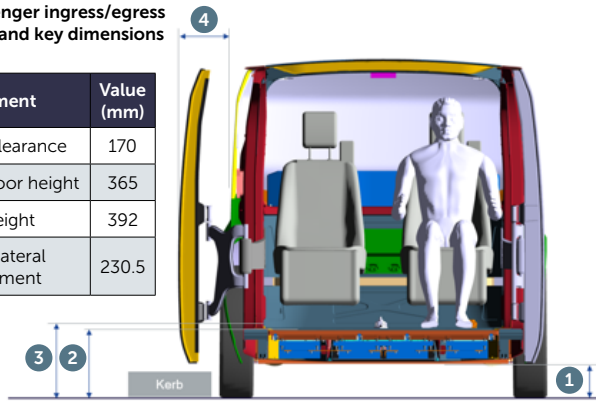
Figure 2. Virtual Reality (VR) image from SEM1 interior visualisation, featuring 95th percentile mannequins

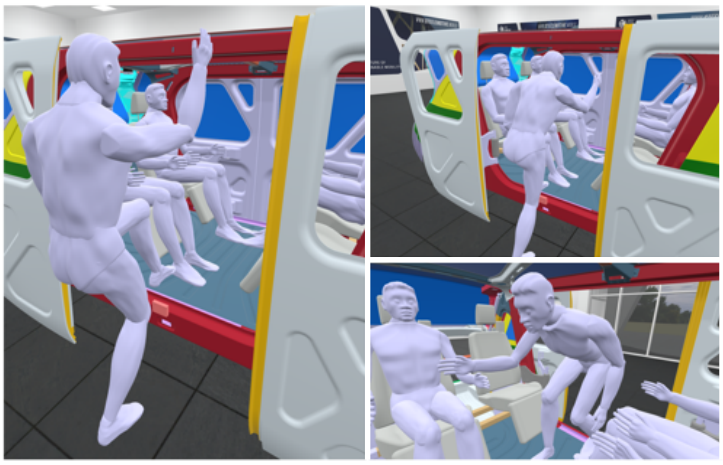
Four-wheel steering facilitates vehicle operational manoeuvrability. The front and rear axles are independently steered, enabling a small turning circle of 7.6m and the potential for low-speed crab steering for enhanced operational mobility. This is important when the vehicle enters or exits pick-up locations, often referred to as kerb management. The Steel E-Motive vehicle can also be fitted with air-sprung suspension, enabling a variable ride height and a kneel-down facility at the point of passenger pick-up/drop-off. The compact AHSS body structure enables the larger steering and chassis systems to be accommodated within the available space.

Passenger ingress and egress is further facilitated by a completely flat interior floor, enabled by the compact and uniform height profile of the vehicle propulsion battery, which is bolted to floor cross members via an innovative carrier frame system. The floor height is optimised to align with standard kerb dimensions, whilst still offering competitive vehicle ground clearance. **Figure 3** shows the key dimensions and VR simulation for occupant ingress and egress.

Figure 3. Passenger ingress/egress VR simulation and key dimensions

	Measurement	Value (mm)
1	Ground clearance	170
2	Interior floor height	365
3	Step-in height	392
4	Kerbside lateral encroachment	230.5





Steel E-Motive Delivers Exceptional Operational Passenger Comfort

Passenger comfort whilst travelling in the vehicle is assured by addressing a number of design features and attributes. The engineering team selected McPherson strut front and rear suspension systems to provide optimal levels of primary ride comfort. Low frequency vibrations from road inputs are minimised as the Steel E-Motive AHSS body structure design was optimised to achieve high modal resonance frequencies. Interior noises generated from road and electric motor sources are minimised due to the high dynamic stiffness of the body structure chassis and powertrain attachment points. Motion sickness can be accentuated in fully autonomous vehicles due to the potential for reduced interaction of passengers with the vehicle and external environment. Finally, both concepts feature large areas of glazing in the body sides and roof, enabling the occupants to maintain visual connection to the exterior, to alleviate passenger motion sickness.

The inherently high stiffness properties of steel result in body structures with a high rigidity, providing a good basis for vehicle ride comfort performance, and minimise noise, vibration and harshness (NVH). The AHSS body structure achieved a very high static torsional stiffness, ensuring a reduction of squeaks and rattles that may occur from large road inputs.

Whilst detailed design of the seating was not undertaken within the scope of the project, sufficient vehicle package space and retaining fixtures to the body structure were accounted for, ensuring that an appropriate, comfortable, safe and functional seating design could be achieved. The cabin and motor compartments have sufficient space and capacity for a complete and appropriately sized HVAC system. For operational safety, cost saving and package space reasons, the cabin windows feature fixed (non-drop) glazing which also maintain a balanced, manageable cabin climate and environment.

Steel E-Motive: A No Compromise Approach to Safety

The safety of the occupants is paramount, given the novel and uniqueness of fully autonomous transportation. Users' impressions and feelings can be enhanced by assurance of the vehicle safety performance. For Steel E-Motive, it was understood that safety standards were unlikely to be relaxed as these vehicles will be deployed in mixed traffic modes together with private and commercial vehicles.

The comprehensive AHSS grade portfolio enabled engineers to tune the body structure to deliver the safety performance required for a MaaS vehicle. Non-conventional geometries were achieved by complementing cold stamping processes with advanced fabrication methods such as press hardening, roll-forming and roll stamping. Coupling these materials and production choices ensured crush and energy absorption where required, and stiffness/strength where cabin intrusion must be mitigated.

Steel E-Motive is compliant with the latest global safety standards which apply to conventional passenger cars and have been adopted and adjusted as appropriate by the project team for autonomous vehicles, as shown in **Table 1**.

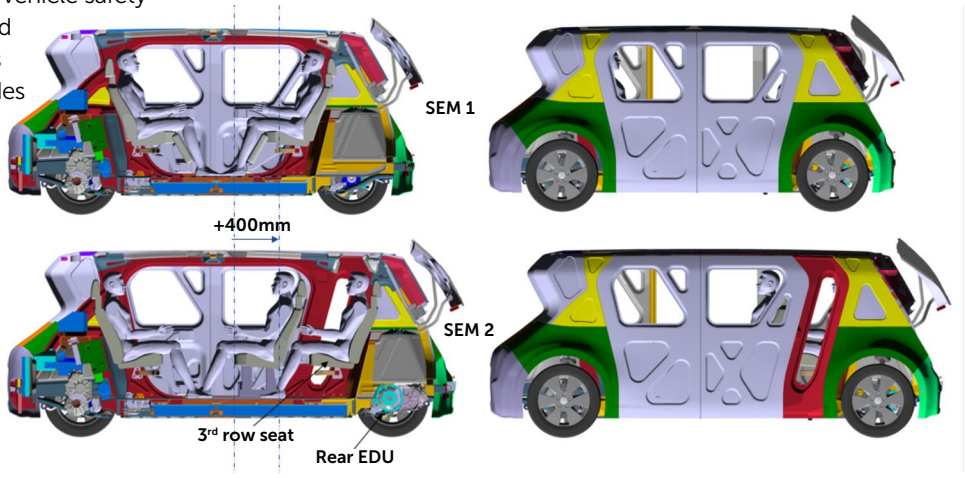
Table 1. Relevant, global crash standards met in development of SEM1

Safety Requirement	Test Standard
Front crash, protection of occupants and battery	Predicted to achieve "good" (highest) rating for two Insurance Institute of Highway Safety (IIHS) tests: 64kph Offset Deformable Barrier (ODB) & 64kph Small Offset Rigid Barrier Overlap (SORB) [based on predicted pulse and intrusion targets] USNCAP 56kph Frontal Rigid Barrier (FRB) – predicted deceleration pulse target and intrusions within defined target No damage to battery for all load cases
Side crash, protection of occupants and battery	Predicted to achieve "good" (highest) rating for IIHS Side Barrier V2 (based on predicted intrusions) USNCAP 32kph side rigid pole. Predicted intrusions are compliant with IIHS "good" rating No damage to battery for all load cases
Rear crash, protection of occupants and battery	Compliant for FMVSS305 EV. Deceleration pulse, intrusion levels within targets No damage to battery
Underbody debris/ battery damage risk	(No prescribed legislation for battery protection at the time of the project). Battery remains undamaged under static point loads applied at several locations on the battery cover
Protection of occupants in roof crush event	IIHS roof crush / FMVSS216 a. Achieves Strength to Weight Ration (SWR) of 9.8 versus >4.0 target to achieve "good" rating

Larger SEM2 Vehicle Provides Increased Passenger Capacity, Functionality

A cost-efficient, modular extended wheelbase vehicle derivative is provisioned for within the Steel E-Motive concept design. SEM2 serves longer distance journeys, including extended commuting, vacations and airport transfers. A third-row seat increases the seating capacity to six occupants. An increased battery capacity enables a greater vehicle range and features an additional Electric Drive Unit (EDU) to deliver the power and torque required for the larger vehicle.

Figure 4. SEM2 extended wheelbase, six-passenger vehicle



Michigan Technological University (MTU) and the Tecnologico de Monterrey (Mexico) conducted additional development studies for the adaptation and rapid conversion of the seated passenger variant of SEM2 to a last-mile delivery vehicle. A rapid, interchangeable seating to in-vehicle locker system was developed, enabling the vehicle to be converted from passenger to delivery vehicle in under 20 minutes – the intention being that the vehicle can operate in passenger transport mode by day and delivery mode at night-time. This adaptability maximises vehicle utilisation and overall operational profitability, creating a positive business case for service providers considering deployment of autonomous ride-sharing vehicles.

Steel E-Motive Provides Accessibility for All

Fully autonomous MaaS vehicles offer the potential to significantly increase access to personalised transportation for persons with mobility challenges. Both SEM1 and SEM2 were designed for this purpose and are compliant with disabled user requirements, ensuring safe and comfortable transportation. A virtual, ergonomic evaluation of vehicle wheelchair access and transportation was undertaken for SEM1 and SEM2 using VR tools, as shown in **Figure 5**.

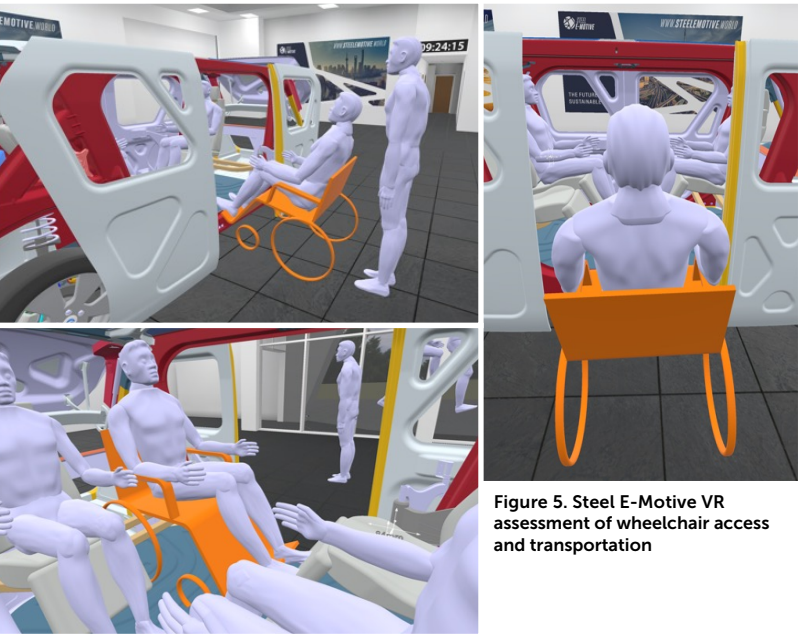


Figure 5. Steel E-Motive VR assessment of wheelchair access and transportation

Summary

Mobility as a Service is expected to grow exponentially in densely populated urban environments. Level 5 autonomy, and their compact and open designs allow attractive levels of passenger comfort, accessibility, convenience and functionality, but are countered by challenges in manufacturing and safety performance.

WorldAutoSteel's Steel E-Motive concepts address these requirements, through the application of the latest AHSS grades in its design. Despite a highly compact design and overall dimensions, a large and spacious interior is enabled, thanks to the unique inward-facing seating configuration and the scissor action side-opening doors.

Four-wheel steering makes Steel E-Motive highly manoeuvrable when operating in congested, urban areas. A flat interior floor, low step-in height and the one-meter opening contributed by the scissor doors facilitate passenger comfort when entering and leaving the vehicle.

The AHSS body structure features compact body structure section profiles, enabling greater passenger accommodation space and maximising the glazed surface area and natural lighting. The vehicle delivers a comfortable journey experience, through its optimized suspension design and high stiffness AHSS body structure and full HVAC system. Both the smaller SEM1 and larger SEM2 vehicles are compliant with disabled user requirements, offering safe and convenient transportation for all. Finally, SEM1 has been tested and is compliant with all relevant global crash standards.

For additional details on the Steel E-Motive project, including specific design and simulation results, visit **steelemotive.world/resources**