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STRATEGIC STUDY OF PLACEMENT OF BATTERY PACK FOR SMALL PASSENGER ELECTRIC VEHICLES

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Abstract - *As the automotive industry expects rapid transition towards electrification, the packaging of most complex and safety critical component also seen as a mammoth task. Our study presents a systematic packaging strategy and location-finalization methodology for integrating a lithium-ion battery pack into a small passenger vehicle. Batteries occupy significant space in electric commercial vehicles, making battery placement a critical design decision. Deciding on battery pack location has impact on various factors like vehicle CG, Vehicle Load distribution, packaging of surrounding aggregates, safety of the battery pack and also of the occupant, Cost impact etc. to name a few. In the electric conversion of the passenger small commercial vehicle, various locations were evaluated—underfloor, rooftop, under-seat, rear overhang & under cabin—with respect to C.G, lateral load transfer, tractive effort, energy consumption & available traction on wheels.*

Each option posed unique challenges like elevated center of gravity, increased drag & traction limited torque. In this study, detailed packaging studies, certain vehicle calculation are made and each location are evaluated with its pros and cons. Study also proposes preferred location for such vehicles. This study provides practical insights into safe, efficient, and scalable battery packaging for small passenger EV platforms.

Key Words: **Small Passenger Vehicle, Battery Packaging, Vehicle C.G, Load Distribution,M2 Category.**

1. INTRODUCTION

Global demand for carbon net zero aims to balance greenhouse gas (GHG) emissions with removal, targeting net-zero by 2050 (or later for some developing countries by, 2070) to limit global warming to 1.5°C.This demand has emphasized on rapid electrification of transportation system across the nations like India and China. While electrification of Locomotives has gained and achieved good stability but the automobile industry is still lacking that growth considering key parameters like Vehicle Range, Safety of key critical component like battery packs, and packaging of larger battery packs in to the vehicle.

The rapid electrification of the passenger vehicle segment—particularly -carrying passenger commercial transport units—demands innovative engineering strategies that balance vehicle performance, passenger comfort, safety, and long-term reliability. At the core of this transformation lies a critical decision: where and how to package the battery.

Our work is focused on the strategic framework for battery packaging and location. It examines a range of influential factors, including available space within vehicle architecture, Center of gravity implications, structural integrity, and high-voltage cable routing challenges—all essential to ensuring safety and compliance with AIS 038 Rev 2 standards.

Several configurations were studied and evaluated based on practical trade-offs such as crash safety, impact on passenger ergonomics, cooling system complexity, and serviceability.

2. PACKAGING STRATEGY

2.1 Vehicle Selection and Conversion

The vehicle chosen for battery packaging is M2 category as per Indian standards with GVW < 5 ton with passenger capacity of more than 8 seats.

Battery capacity under consideration is 60-65KWh & battery pack weight range is 180-210 kg.
Vehicle Configuration is Front Axle Driven, 4X2, With E-axle Configuration.

Fig. 1. General Battery pack design

Fig. 2. General EV Vehicle layout

2.2 Vehicle Selection and Conversion

Vehicle Co-Ordinate System (VCS) is defined as per individual vehicle CAD environment requirements. In general, below Scheme shows VCS Position and Vehicle Directions.

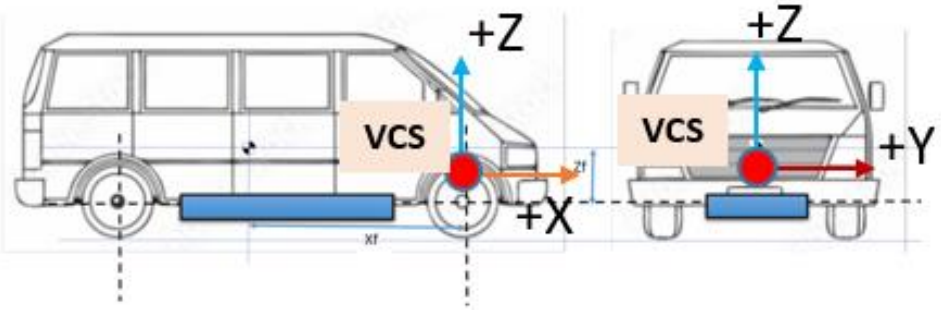

Fig 3: Vehicle Co-Ordinate System (VCS) and Vehicle Level Direction

3. Evaluation of Strategic Packaging Locations of Battery

The DMU (Digital Mock Up) study carried out for various battery pack sizes applicable for said application.
The each battery pack location Study involved,

- Impact on vehicle C.G,
- Vehicle Weights Distribution
- Accessibility and Serviceability
- Packaging constraints due to surrounding aggregates

Evaluation study for various locations described below –

Layout 1: – Battery placement – Between Chassis Structure –

The battery was placed between the front & rear axles approximately at center of vehicle wheelbase. At said locations important parameter evaluated are Vehicle Ground Clearances, Vehicle Ramp Over angle, and Necessary protection needed against stone hitting, Water Splashing and Mud Accumulation possibility in addition to the ones listed above.

The battery placement was done such as ground clearance least impacted. Compared to its ICE variant. The layout 1 is shown in fig 4.
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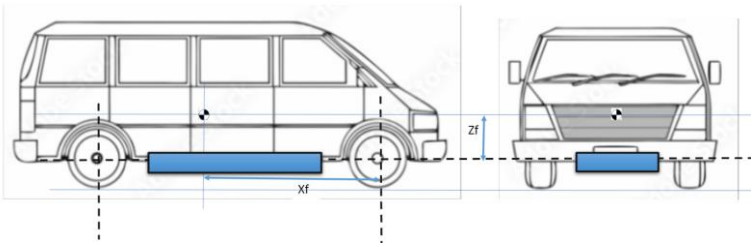

Fig 4: Battery placement - Underfloor between the axles

Layout 2: – Battery placement – Mounted on rooftop

In this layout battery was mounted at the roof top of the vehicle. This was done as it was easy to mount with minor modifications on body. Additionally, the battery covers were designed for aesthetically and aerodynamic considerations as it was completely visible from outside. The layout is shown in fig 5.

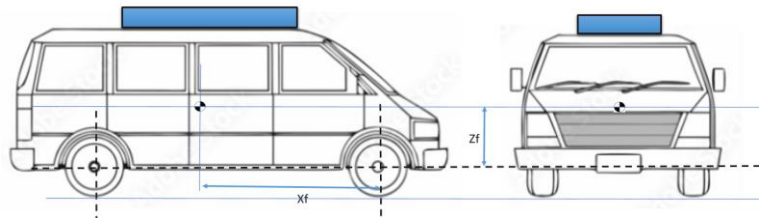

Fig 5: Battery placement – Mounted on rooftop

Based on the technical analysis, the height of the C.G increases in this layout which impacts vehicle dynamic manoeuvre capability.

Layout 3: – Battery placement – At BIW End (Below Last Row Seat)

A new location was selected to mount the battery at rear side of vehicle. The modification required to elevate the floor. Elevated floor impacts the head room for rear seating passenger. These position also calls for minimum modification in surrounding layout.

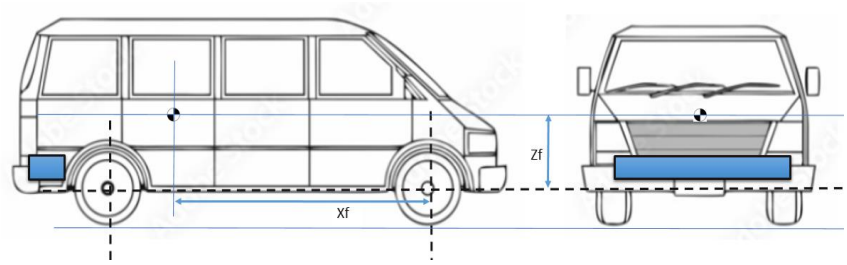

Fig 6: Battery placement – Rear Side (Below Last Row Seat)

Technical analysis indicates, the C.G will reduce compared to rooftop mounting but will affect the grade-ability. Packaging at the rear side will have the risk of damaging the battery due to rear end crash from following vehicle.

Layout 4: – Battery placement – Mounted Inside cabin below Seats.

Battery was placed inside the cabin under the passenger seats. The advantage here is that battery will be safe from hitting the road, bumpers, etc. as compared to other placements and will have low C.G. Split battery proposal can also be useful to improve the battery capacity and vehicle range.

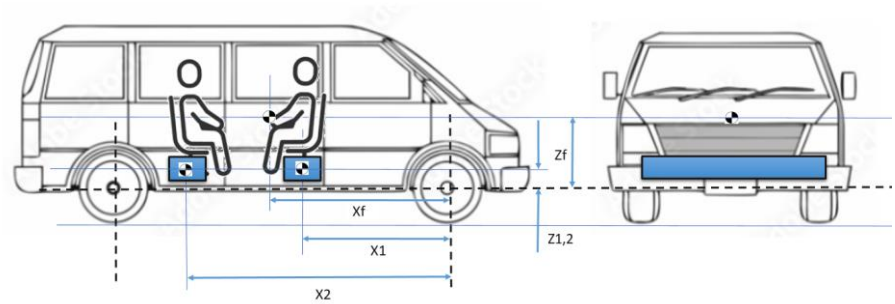

Fig 7: Battery placement – Mounted Inside cabin below Seat

4. Vehicle C.G and Load Distribution Calculations Methodology:

Below Flow chart helps to understand and calculate the Vehicle C.G Calculation with all the aggregates in place, Load distribution on Front Axle and Rear Axle in Laden and Un-laden condition.

This calculation process is carried out for all 4 layouts discussed above to study the impact of Battery Pack Placements On Vehicle C.G and Load Distribution.

The calculations for all 4 layouts were done as per flow chart below –

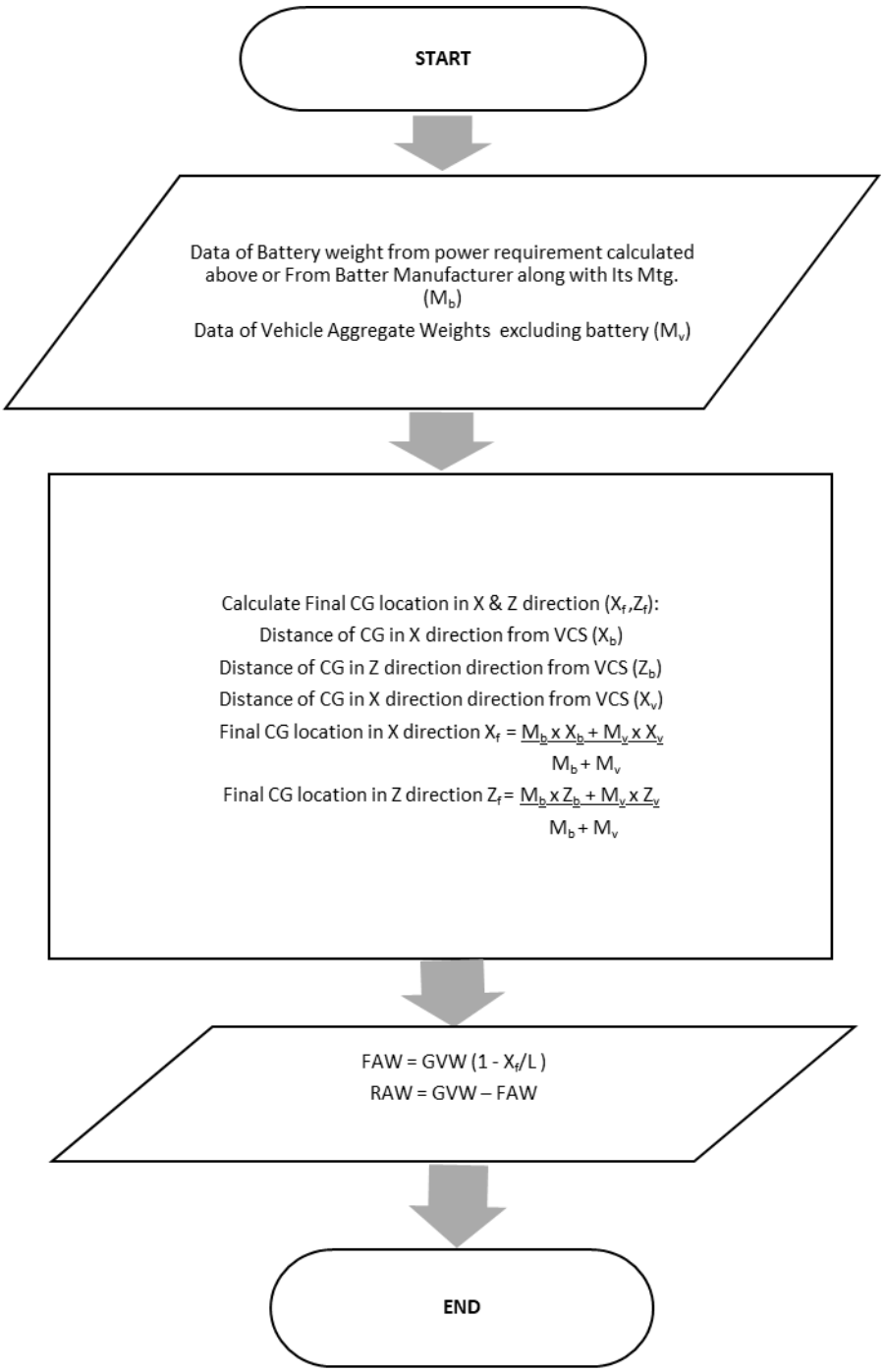

Fig 8: Flow Chart- Calculation of Vehicle C.G and Load Distribution on FA and RA.

5. Packaging Study and Observation with Various Battery Location Proposal

Various layouts studies done in earlier sections have certain benefits and certain limitations. Additional study of CG and Load distribution had deepened the insights about the dynamics of the vehicle and packaging benefits and limitations about a particular layout.

	Pros	Cons
Battery placement – Between Chassis Structure	• Lowers centre of gravity (CG) • Better weight distribution in vehicle FAW and RAW. • Good traction at all 4 wheels • Good thermal management and crash protection • Simplified high-voltage (HV) wiring.	• Ground Clearance and Vehicle Ramp Over angle may get compromised. • Intrusion might be needed in BIW for accommodating the battery pack.
Battery placement – Mounted on rooftop	• Easy to mount • Ease of accessibility • No intrusion of BIW inside cabin for accommodating the battery pack. • In case of Fire incidents, rescue can be easy • Cooling system packaging will be simple. • Weight distribution is better with this layout.	• Vehicle CG point shifted in Z-direction resulting in increase in Vehicle roll over tendency. • Results in increase of vehicle Drag Force. • Requires heavy structure at the top of the vehicle to sustain battery load. • HV cable routing will be lengthy resulting in higher cost impact.
Battery placement – At BIW End (Below Last Row Seat)	• BIW layout is open for better utilization of seating layout. • LOW floor height at center portion can be possible. • In case of Fire incidents, rescue can be easy • Harness routing for HV cable will be simpler and optimized. • Layout is better suitable for Rear Wheel Drive option.	• Considerable reduction in vehicle tractive force front wheel due to shift of C.G away from Front Axle. • Affects crash safety, from Rear • To meet Departure angle requirement, rear floor need to be lifted quite up in Z direction. Resulting in Reduces headroom for rear seats. • Battery damage in case of Crash from Rear may affect its life and further usability.
Battery placement – Mounted Inside cabin below Seats.	• Efficient space utilization. • Lowers centre of gravity (CG) • Better weight distribution in vehicle FAW and RAW. • Good thermal management and crash protection • Simplified high-voltage (HV) and LV Routing. • Layout is better utilized for all Wheel Drive option.	• Serviceability will be bit complex • In case of Fire Incident, possibility of occupant safety is critical. • Ground Clearance and Vehicle Ramp Over angles may get compromised to some extent.

6. CONCLUSION

Out Come of the study is to share the insights of various possible layout of battery pack in small passenger vehicle. The impact of battery pack being one of the highest weight contributor on vehicle C.G and load distribution plays a vital role and cannot be overlooked.

Each location has its own benefits and drawbacks, so it is important to find a balance of all based on application of the product. Said document will certainly help to form the basis to identify and work out the suitable position to end users.

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