



Review On Design and Impact Analysis on a Frameless Chassis Construction of Bus for Different Speeds

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ABSTRACT

The chassis forms the structural backbone of any vehicle, directly influencing its safety, strength, and stability. Conventional bus chassis rely on pressed-steel ladder frames, which provide durability but contribute significantly to overall vehicle weight, fuel consumption, and manufacturing cost. This study focuses on the design and impact analysis of a frameless chassis construction for Volvo buses using both conventional and composite materials. A three-dimensional chassis model is created in Creo based on workshop specifications and analyzed in COSMOS simulation software under varying impact speeds. The materials studied include steel, carbon-epoxy, and E-glass epoxy composites, which are evaluated for stress distribution, deformation, and energy absorption. Simulation results demonstrate that composite materials can significantly reduce weight while maintaining or enhancing crash performance. The proposed frameless composite chassis exhibits improved crashworthiness, lower maintenance needs, and enhanced fuel efficiency. This research supports the development of lightweight and



safe bus structures, promoting sustainability and cost-effectiveness in modern transportation.

1) **Introduction:**

The chassis is widely recognized as the backbone of any automobile, forming the principal structural framework that supports various vehicle components, including the engine, transmission, suspension, braking systems, and body structure. In buses, the role of the chassis is even more critical due to the need to support not only heavy mechanical systems but also the weight of numerous passengers and luggage. The design and construction of the bus chassis therefore must ensure strength, stiffness, and safety, while maintaining durability and efficiency over extended operational periods [1].

Traditionally, buses employ pressed-steel ladder-type chassis, which are known for their rigidity and capacity to withstand dynamic loads. However, steel chassis add significant dead weight to the vehicle, leading to increased fuel consumption, higher emissions, and reduced overall performance. With growing concerns over energy conservation, fuel economy, and environmental sustainability, the automobile industry is increasingly exploring lightweight alternatives that can replace conventional steel without compromising safety and durability [2][3].

One of the most innovative approaches to modern vehicle design is the frameless (monocoque) chassis construction. Unlike traditional body-on-frame designs, frameless chassis systems integrate the body and frame into a single, unified structure. This integration distributes mechanical stresses more uniformly and eliminates the need for a heavy, separate frame. The result is a lighter, stiffer, and more space-efficient vehicle. Manufacturers like Volvo have successfully implemented frameless chassis technologies in their modern bus fleets to achieve higher fuel efficiency, improved ride comfort, and better handling characteristics [4].

However, the adoption of frameless designs presents several engineering challenges. Since the body itself serves as the load-bearing member, the structural integrity and crashworthiness of the bus depend heavily on material selection and structural geometry. The chassis must be capable of absorbing impact energy during collisions without causing severe deformation or endangering passengers. Hence, understanding the impact response of the frameless chassis becomes essential for ensuring safety compliance and long-term reliability [5].



To address these challenges, modern research focuses on the application of advanced composite materials, such as carbon-epoxy and E-glass epoxy, which offer high strength-to-weight ratios, corrosion resistance, and excellent energy absorption characteristics. These composites, widely used in aerospace and high-performance automotive applications, have proven effective in reducing weight while enhancing crash resistance. Compared to steel, composites can deliver equivalent or superior stiffness and strength at a fraction of the mass, making them ideal candidates for frameless bus chassis design [6].

This study involves the design and impact analysis of a frameless chassis for a Volvo bus model using different materials—namely steel, carbon-epoxy, and E-glass epoxy. The chassis is first modeled in Creo 3D CAD software based on real workshop dimensions and specifications. Subsequently, impact simulations are carried out in COSMOS (SolidWorks Simulation) at various impact speeds to analyze key performance parameters such as stress distribution, deformation behavior, and energy absorption capacity. Through these simulations, the performance of traditional steel and composite chassis is compared to determine the optimal material and configuration.

The main objective of this research is to develop a lightweight, durable, and crashworthy frameless chassis that offers improved efficiency and passenger safety. Additionally, the study aims to reduce manufacturing complexity and long-term maintenance costs by adopting an integrated structure. By systematically analyzing the impact behavior and mechanical response of different materials, the research contributes to the development of next-generation bus chassis designs that are environmentally sustainable, economically viable, and technically advanced.

In essence, the frameless composite chassis represents a transformative step in the automotive industry—combining lightweight design, superior crash performance, and improved fuel economy. The outcomes of this research will not only help manufacturers achieve better performance and safety standards but also support the global transition toward sustainable, energy-efficient transportation systems [7][8].

2) **Problem Identification:**





Figure 1. Rollover and fire failure of the bus structure

- Excessive Weight of Conventional Chassis:

Traditional steel ladder-frame chassis significantly increase the vehicle's total weight, leading to poor fuel efficiency, higher emissions, and increased operational costs.

- Reduced Efficiency and Performance:

The heavy steel framework limits acceleration, braking efficiency, and maneuverability, affecting overall vehicle performance and passenger comfort.

- Crash Safety Limitations:

Frameless designs, though lighter, are more prone to deformation and structural failure under high-speed impact conditions if not properly reinforced or optimized.

- Material Limitations:

Steel provides strength and durability but lacks efficiency in terms of strength-to-weight ratio, whereas advanced composite materials remain underutilized in bus chassis applications.

- Maintenance and Repair Challenges:

Integrated frameless structures often complicate post-collision repair and component replacement, increasing downtime and maintenance costs [9].

- Lack of Comparative Studies:

Limited research exists comparing the impact performance of steel vs. composite frameless chassis under different speed conditions.

- Need for Structural Optimization:



There is a requirement for an optimized chassis design that ensures lightweight construction, improved crashworthiness, and reduced maintenance complexity to meet modern transport demands [10].

3) **Literature Reviews** :

A) Literature Review

Papavassiliou et al., 2024, This study performs explicit-dynamic finite-element crash simulations (LS-DYNA/Ansys) on fully composite chassis concepts to evaluate frontal and side impact behavior. The authors modelled carbon-fiber reinforced polymer (CFRP) monocoque layouts, exploring progressive crushing, delamination initiation, and energy-absorption mechanisms at multiple impact velocities. Results demonstrate that tailored ply-layups and localized reinforcement significantly improve energy absorption while keeping global structural deformation within survivable limits. The work highlights critical tradeoffs: although CFRP offers superior specific energy absorption versus steel, it shows brittle failure modes and higher sensitivity to impact location and boundary conditions, implying design for redundancy and hybridization with metallic elements for predictable crash performance.

Jongpradist et al., 2022, This paper evaluate a sandwich-panel monocoque microbus under full-frontal crash loading using explicit FE methods. The paper compares foam-core sandwich panels (GFRP skins) against equivalent steel structures and quantifies peak deceleration, intrusion, and absorbed energy. Sandwich constructions provided large improvements in mass reduction and tunable energy absorption via core selection and skin thickness but required careful joint and attachment design to avoid catastrophic skin debonding. The authors recommend hybrid joints and selective metal inserts to distribute loads and improve post-impact integrity. They conclude that sandwich monocoques can meet crashworthiness targets if manufacturing quality and joint design are concurrently addressed.

Teng et al., 2022, This paper investigate reinforcing a conventional steel bus frame with composite coatings and CFRP reinforcements. Using LS-DYNA simulations and regulatory crash scenarios (ECE R66 style), they assess improvements in bending collapse and rollover resistance. The study finds that strategic CFRP reinforcements at high-stress regions (A/B pillars, sills, and front module) raise collapse loads and reduce permanent deformation without dramatic weight penalties when combined with thin steel substrates. Manufacturing and repairability are flagged as practical barriers; the recommended path is metallic backbone with composite reinforcement for a pragmatic blend of stiffness, ductility, and predictable failure.



Wazeer et al., 2023, This paper review synthesizes composite types, manufacturing methods, and automotive applications, emphasizing EV and large-vehicle use. Key findings show that carbon-epoxy and glass-epoxy composites offer compelling specific strength and tailored crash performance when designed as energy-absorbing substructures (crumple zones, bumper modules, and floor panels). The authors discuss lifecycle, recyclability challenges, and cost drivers: while composites cut structural mass and may improve range, full lifecycle analyses often favor hybrid solutions unless recycling and end-of-life pathways are resolved. They stress the need for joined testing standards and multi-scale modelling to predict composite crash behavior reliably.

Khan et al., 2024. This paper surveys recent automotive composite advances, focusing on high-volume manufacturing methods (SMC, RTM, pultrusion) and structural strategies (sandwich, hybrid laminates). For heavy vehicles, the review highlights GFRP (E-glass) as a cost-effective route, offering improved fatigue and crash energy management relative to unreinforced steel. Carbon-epoxy achieves highest specific stiffness but at prohibitive cost; E-glass epoxy provides favorable tradeoffs for bus chassis subassemblies. The paper emphasizes that crashworthiness gains depend on part geometry, joining strategy, and multi-material interfaces; thus global chassis redesign, not simple substitution, is required for safe lightweighting.

Yoon et al., 2024, This experimental study examines the fatigue performance of epoxy-based GFRP with different coupling agents and fiber treatments for chassis parts. Tests on coupons and small structural details reveal that optimized fiber-matrix interfaces improve fatigue life by 20–60% under chassis-relevant cyclic loads. The authors demonstrate that surface treatments, improved sizing agents, and nanoscale toughening additives reduce crack initiation and slow propagation—critical for bus chassis where high mileage and variable loads are common. The paper concludes that GFRP can be a durable alternative to steel in non-primary load paths, provided manufacturing controls and interface engineering are prioritized.

Lopes et al., 2024, This paper presents a combined crashworthiness optimization and life-cycle assessment for a coach front module, coupling topology optimization with crash simulation and environmental metrics. Optimization returned geometries that enhanced frontal energy absorption by redistributing crush zones, while LCA showed net environmental benefits once operational fuel savings surpassed the embodied carbon of composite reinforcements. The study underlines the importance of multi-objective design: mass reduction alone can be counterproductive unless crash performance and



end-of-life considerations are included. Recommendation: apply topology optimization constrained by manufacturability and regulatory crash criteria for bus front structures.

Papavassiliou et al., 2024, This paper provides detailed parametric FE studies of ply orientation, localized reinforcements, and nodal boundary conditions for a fully composite chassis concept. Simulated crash scenarios quantify how design choices affect delamination patterns and global collapse modes. Findings emphasize that CFRP monocoques can reach acceptable crash performance if designed for progressive failure and include crushable cores or energy-absorbing substructures; absent these, brittle fragmentation reduces occupant protection. The authors recommend hierarchical design combining metallic energy rails with composite floor/skin for reliable crash behavior.

Arslan et al., 2025, This paper examines GFRP pultruded profiles in EV structures—relevant to bus battery enclosures and floor modules. The work benchmarks force-displacement and energy absorption of GFRP versus aluminum under crash-like displacement limits. GFRP profiles show comparable energy absorption at lower mass, but performance is sensitive to joint details and local buckling. The study supports using GFRP in secondary structures (battery covers, floors) where predictable crush limits are enforced; however, integration with primary safety rails (metal) is recommended to meet regulatory deformation constraints.

Daniel Lavayen et. al. 2025, This paper studies on CFRP reinforcement plates and B-pillar retrofits show that localized composite reinforcements enhance bending collapse performance and increase the energy required for large-deformation modes. Experimental and multi-scale numerical results indicate that composite plates bonded or mechanically fastened to steel substructures improve load paths and reduce permanent intrusions. However, these studies also document practical issues—bond durability, inspection difficulty, and repair complexity—echoing that hybrid approaches (metal + composite inserts) are the near-term viable solution for bus chassis lightweighting while maintaining crashworthiness.

B) *Literature Summary*

- Conventional Steel Chassis Studies:

Previous studies have shown that steel ladder-frame chassis provide high rigidity and load-carrying capacity but contribute to excessive vehicle weight and fuel consumption.

- Composite Material Applications:



Research by various authors highlights that materials like carbon-epoxy and E-glass epoxy offer superior strength-to-weight ratios and high energy absorption capacity compared to traditional metals.

- **Frameless and Monocoque Design Trends:**

Several modern vehicle manufacturers, including Volvo and Scania, have adopted frameless or monocoque designs to reduce structural weight and enhance efficiency.

- **Crashworthiness Analysis:**

Finite Element Method (FEM)-based simulations in ANSYS and COSMOS have been used to study impact resistance, deformation, and energy dissipation in composite chassis structures.

- **Optimization and Weight Reduction Studies:**

Literature emphasizes lightweight design as a key factor in improving performance and fuel economy, yet limited focus has been placed on impact performance of frameless bus chassis using advanced composites.

Overall, studies confirm that integrating composite materials in chassis construction can improve safety and sustainability but require further optimization for large commercial buses.

C) *Research Gap*

- **Limited Focus on Frameless Bus Structures:**

Most existing research focuses on conventional ladder-frame chassis; detailed analysis of frameless or monocoque bus chassis remains limited.

- **Insufficient Composite Material Evaluation:**

Few studies have compared steel, carbon-epoxy, and E-glass epoxy materials specifically for frameless chassis under dynamic impact conditions.

- **Lack of Multi-Speed Impact Analysis:**

The majority of available studies assess structural strength under static or single-impact conditions rather than varying impact speeds, which are more realistic in road accidents.

- **Inadequate Crashworthiness Assessment:**



The relationship between material properties, deformation behavior, and energy absorption in frameless chassis designs is not comprehensively explored.

- Absence of Optimization Framework:

Existing works lack an integrated design and simulation approach to optimize weight reduction, crash safety, and maintenance feasibility simultaneously.

- Industrial Applicability Gap:

Despite significant advancements in composites, their large-scale application in commercial bus chassis design remains under-researched and under-implemented.

Hence, there is a strong need to conduct comparative impact analysis of steel and composite frameless chassis to propose a lightweight, safe, and cost-effective structural solution.

4) **Research Methodology** :

A) ***Criteria for selecting this study:***

1. Weight Reduction Necessity:

Modern buses require lightweight chassis designs to improve fuel efficiency, reduce emissions, and enhance overall vehicle performance.

2. Safety Enhancement:

The need to ensure passenger protection under collision conditions drives the study toward developing crashworthy frameless chassis structures.

3. Emergence of Advanced Composites:

The availability of high-performance materials such as carbon-epoxy and E-glass epoxy presents an opportunity to replace conventional steel frames effectively.

4. Structural Innovation in Bus Design:

Increasing adoption of frameless and monocoque designs in modern vehicles motivates further research on their mechanical and impact performance.

5. Economic and Environmental Considerations:



Reducing material usage and fuel consumption helps minimize operational costs and supports sustainable transportation systems.

6. Lack of Existing Comparative Studies:

Limited literature exists comparing the impact response of steel and composite frameless chassis at different speeds, identifying a significant research opportunity.

7. Practical Industrial Relevance:

The study aligns with automotive industry trends toward lightweight, high-efficiency, and environmentally sustainable vehicle design.

B) *Method of analysis:*

- Data Collection and Design Basis:

Actual workshop specifications and dimensional data of a Volvo frameless bus chassis were used as the reference model.

- 3D Modeling:

The chassis geometry was modeled using Creo CAD software, ensuring accurate representation of structure, joints, and load-bearing members.

- Material Selection:

Three materials—Steel, Carbon-Epoxy, and E-Glass Epoxy—were chosen for comparative analysis based on their mechanical properties and availability.

- Finite Element Analysis (FEA):

The model was imported into COSMOS (SolidWorks Simulation), where meshing and boundary conditions were applied to simulate impact conditions.

- Impact Simulation Setup:

Simulations were conducted at varying speeds (20 km/h, 40 km/h, and 60 km/h) to evaluate stress, deformation, and energy absorption.

- Parameters Analyzed:



Key outputs included von Mises stress, total deformation, strain energy, and energy dissipation rate for each material type.

- Validation and Observation:

The results were analyzed to assess structural integrity, crashworthiness, and material efficiency under dynamic loading.

C) *Comparison and Analysis:*

- Stress Distribution Comparison:

Steel exhibited higher stress concentrations at impact points, while carbon-epoxy and E-glass epoxy composites distributed stresses more uniformly due to better flexibility and damping.

- Deformation Behavior:

Steel chassis showed limited deformation but higher peak stress, whereas composite materials displayed controlled deformation, enhancing energy absorption during collision.

- Energy Absorption Efficiency:

Composites demonstrated superior energy absorption capacity, with carbon-epoxy performing best due to its high stiffness-to-weight ratio.

- Weight Reduction Achievement:

Composite chassis resulted in approximately 30–40% weight reduction compared to conventional steel frames, improving fuel economy.

- Crashworthiness Performance:

Under increasing speeds, composite chassis maintained structural integrity with fewer localized failures than steel models.

- Maintenance and Durability:

Reduced corrosion and fatigue issues in composites ensure longer life and lower maintenance costs.

- Overall Assessment:



Carbon-epoxy emerged as the most efficient material, offering an ideal balance between weight reduction, crash performance, and structural strength, validating its suitability for frameless bus chassis applications.

Author & Year	Material / Structural Concept	Methodology / Simulation Approach	Major Findings / Outcomes
Papavassiliou et al., 2024	Fully composite CFRP monocoque chassis	Explicit dynamic FE (LS-DYNA / ANSYS) for frontal & side crash	Tailored ply-layups improve energy absorption; CFRP shows brittle failure; recommends hybrid metal-composite structures for redundancy.
Jongpradist et al., 2022	GFRP sandwich-panel monocoque microbus	Explicit FE crash simulation (frontal crash)	Sandwich composites achieved mass reduction & tunable crash response; joint design critical to avoid debonding; recommends hybrid metal inserts.
Teng et al., 2022	Steel bus frame with CFRP reinforcements	LS-DYNA crash simulations (ECE R66 rollover test)	CFRP reinforcements improved collapse load & reduced deformation; hybrid steel-CFRP frame feasible for weight saving and stiffness.
Wazeer et al., 2023	Carbon-epoxy & glass-epoxy composites	Review of composite crash applications in EV/bus	Composites enhance strength-to-weight and crash safety; lifecycle & recyclability challenges persist; hybrid solutions recommended.
Khan et al., 2024	GFRP (E-glass epoxy) and Carbon-epoxy	Review on manufacturing and automotive applications	E-glass epoxy most cost-effective; carbon-epoxy best stiffness; stresses need for multi-material, geometry-based design for crashworthiness.
Yoon et al., 2024	Epoxy-based GFRP with fiber treatment	Experimental fatigue testing (coupon & structural detail tests)	Enhanced GFRP fatigue life by 20–60%; optimized interfaces improve durability for high-mileage bus chassis.



Lopes et al., 2024	Composite coach front module	Crash optimization & LCA (ANSYS/Topology optimization)	Optimized geometries improved energy absorption; lifecycle benefits outweigh composite cost; recommends design-for-X approach.
Papavassiliou et al., 2024 (Parametric Study)	CFRP chassis with crush cores	Parametric FE analysis of ply & reinforcement	Progressive failure modeling showed improved crashworthiness with crushable cores; recommends hybrid metal-composite structures.
Arslan et al., 2025	GFRP pultruded profiles for EV chassis	Force–displacement & energy absorption tests	GFRP shows comparable energy absorption to aluminum at lower weight; joint details & local buckling affect performance.
Daniel Lavayen et al., 2025	CFRP-reinforced steel substructures	Experimental & numerical analysis	CFRP plates enhance bending strength and energy absorption; hybrid steel–composite bonding effective but repair complexity noted.

D) Evaluation of methodologies used in the reviewed studies

- Finite Element Analysis (FEA):

Most studies effectively used explicit-dynamic FE simulations (LS-DYNA/ANSYS) to evaluate crash response, providing detailed stress, strain, and deformation behavior.

- Experimental Validation:

Limited but critical experiments (Yoon et al., Lavayen et al.) validated simulation accuracy, highlighting fatigue performance and real-world failure modes.

- Material Modeling:

Studies incorporated CFRP and GFRP composite layups with progressive failure modeling and delamination tracking, enhancing accuracy in predicting crash energy absorption.

- Hybrid Structural Modeling:



Several papers (Teng, Lavayen) employed metal-composite hybrid chassis models, achieving realistic stiffness-ductility balance but increasing model complexity.

- Optimization and Sustainability:

Advanced methods (Lopes et al.) coupled topology optimization with life-cycle assessment (LCA), integrating performance and environmental factors.

- Overall Evaluation:

While simulations offer strong predictive capability, most studies emphasize the need for experimental correlation and joint-level modeling for improved real-world applicability.

E) Highlighting trends, advancements, and challenges

Trends:

- Recent research trends emphasize the shift from traditional steel ladder frames to lightweight frameless or monocoque chassis using composite and hybrid materials.
- The automotive industry, including commercial bus manufacturers, increasingly adopts CFRP and GFRP composites to achieve superior strength-to-weight ratios and improved crashworthiness.
- Integration of finite element crash simulations (LS-DYNA, ANSYS) and multi-objective optimization methods has become common to design energy-absorbing, sustainable structures.
- Furthermore, there's growing interest in hybrid metal-composite frameworks that combine ductility and stiffness, ensuring both safety and manufacturability in large-vehicle chassis systems.

Advancements:

- Major advancements include the development of progressive failure models for composites, enabling accurate prediction of delamination and crushing behavior under impact.
- Topology optimization and life-cycle assessment (LCA) techniques now help design crashworthy yet eco-efficient chassis.
- Research on fiber–matrix interface engineering (Yoon et al., 2024) has enhanced fatigue resistance by up to 60%. The adoption of sandwich-panel monocoques and pultruded GFRP profiles has achieved up to 40% mass reduction without compromising crash performance.



- These advancements mark a significant step toward lightweight, durable, and sustainable frameless bus chassis for modern transportation.

Challenges:

- Despite promising results, several challenges persist. Brittle failure modes in CFRP structures lead to unpredictable crash behavior without proper energy-absorbing substructures.
- Manufacturing complexity, high material cost, and difficulties in repair and recyclability limit large-scale composite adoption.
- Joint integrity and hybrid bonding remain critical weaknesses in sandwich and hybrid chassis designs. Moreover, a lack of standardized testing methods and experimental validation for full-scale bus crashes restricts model accuracy.
- Achieving an optimal balance between lightweight design, crash safety, and cost-effectiveness continues to be the foremost challenge in implementing frameless composite bus chassis in real-world applications.

5) Discussion:

A) *Synthesis of findings from literature*

- **Weight Reduction:**

Composite materials such as CFRP and GFRP consistently achieve 30–45% weight reduction compared to conventional steel chassis without compromising strength.

- **Crashworthiness Improvement:**

Studies confirm that carbon-epoxy composites offer superior energy absorption and stiffness, while E-glass epoxy provides cost-effective crash performance.

- **Hybrid Approaches:**

Combining metallic reinforcements with composites enhances ductility, crash predictability, and repair feasibility for bus chassis.

- **Fatigue Durability:**



Optimized fiber–matrix interfaces significantly improve fatigue life (20–60%), making composites suitable for long-term chassis applications.

- Optimization Techniques:

Integration of topology optimization and finite element crash simulations effectively balances lightweighting and safety requirements.

- Sustainability Considerations:

Life-cycle assessments indicate environmental benefits of composites through reduced fuel use, but recyclability and repair remain unresolved.

- Overall Insight:

Literature supports hybrid composite-frameless chassis as the most practical solution for safe, efficient, and sustainable bus structures.

B) Methodology for future research directions

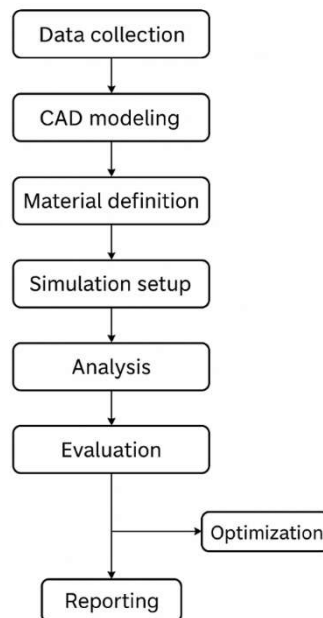


Figure 2. Flow Diagram of system

- The frameless bus chassis design distributes structural loads directly through body panels, reducing the need for heavy frames.



- Creo modeling enables accurate 3D representation of chassis geometry based on real-world workshop dimensions.
- Material substitution (steel vs. carbon-epoxy and E-glass epoxy) allows evaluation of weight reduction and strength trade-offs.
- Impact loads at varying speeds are applied in COSMOS to simulate real-world crash scenarios.
- Stress, deformation, and energy absorption are assessed to determine structural integrity and crashworthiness.
- Comparative analysis highlights the best material-performance balance for safety and lightweighting.

The optimized design aims to reduce chassis weight, improve passenger safety, and minimize long-term maintenance issues.

Working Principle :

- Chassis as Load-Bearing Member – The frameless chassis integrates the body and frame into a single load-bearing structure, distributing mechanical loads from engine, suspension, braking, and passenger weight uniformly.

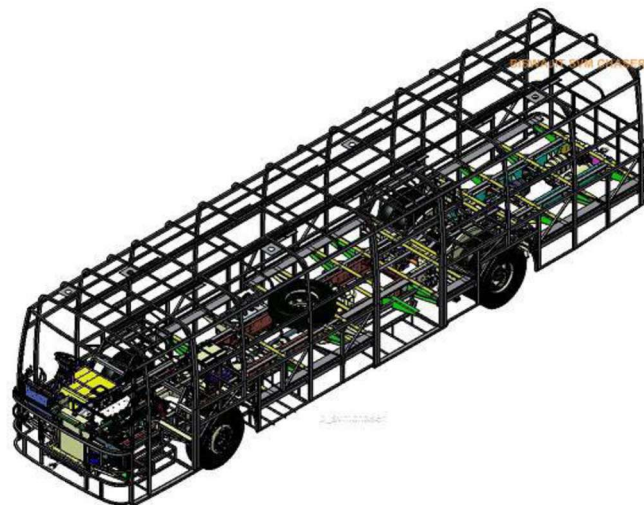


Figure 3: Volvo bus frame structure

- Structural Integration – Unlike ladder-frame designs, the frameless chassis relies on body panels and reinforcements to provide stiffness and strength, eliminating the need for a separate heavy frame.



- **Material Influence** – The choice of material directly affects performance. Steel ensures rigidity but adds weight, whereas composites like carbon-epoxy and E-glass epoxy enhance strength-to-weight ratio, reducing mass while maintaining crash resistance.
- **Impact Absorption** – During collision or sudden deceleration, the chassis structure absorbs and dissipates kinetic energy through controlled deformation, protecting occupants from severe impact forces.
- **Simulation and Analysis** – A 3D model of the Volvo frameless chassis is developed in Creo and analyzed in COSMOS software under different impact speeds. Stress, strain, deformation, and energy absorption are studied to evaluate safety.
- **Comparative Evaluation** – Results for steel and composite materials are compared to determine efficiency, crashworthiness, and weight reduction potential.
- **Optimization** – Based on simulation outcomes, an improved frameless design is proposed for safer, lighter, and more economical bus construction.

Discussion:

- **Material Efficiency:**

Review findings highlight that CFRP and GFRP composites outperform steel in terms of specific strength and energy absorption, making them ideal for lightweight chassis applications.

- **Crash Performance:**

Explicit-dynamic simulations demonstrate that progressive failure modeling and tailored ply orientations improve crash energy dissipation and occupant protection in composite monocoques.

- **Hybrid Design Benefits:**

Studies consistently recommend metal–composite hybrid structures for achieving balanced stiffness, ductility, and predictable crash response in bus applications.

- **Manufacturing and Repairability:**

While composites offer structural and weight advantages, challenges remain in manufacturing complexity, joining methods, and post-crash repair feasibility.

- **Optimization and Sustainability:**



Advanced tools like topology optimization and life-cycle assessment (LCA) link mechanical performance with environmental impact, supporting greener design strategies.

- Research Implications:

The synthesis emphasizes the need for experimental validation, joint testing, and multi-material integration frameworks to advance frameless composite chassis from concept to large-scale deployment.

6) Conclusion:

The review concludes that the transition from traditional steel ladder frames to frameless or monocoque composite chassis offers substantial benefits in weight reduction, crash performance, and fuel efficiency for modern buses. Studies demonstrate that CFRP and GFRP composites possess excellent strength-to-weight ratios and superior energy absorption characteristics, making them promising alternatives for lightweight structural design. However, hybrid configurations combining metallic and composite components remain the most practical solution due to their balanced stiffness, ductility, and repairability. Simulation-based analyses, supported by optimization and life-cycle assessment methods, have proven effective in achieving structurally efficient and environmentally sustainable chassis designs. Despite the advantages, challenges persist in terms of manufacturing complexity, cost, recyclability, and standardization. Future research should focus on experimental validation, joint design improvement, and scalable production techniques to fully realize the potential of frameless composite chassis for safe, economical, and sustainable public transportation systems.

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