Reducing the Weight of a Bus Body Frame by 17% Without Compromise to Performance or Safety

The rise in fuel costs in most parts of the world have forced vehicle manufacturers to produce ever more efficient products to meet customer demands. Bus manufacturers need to create vehicles which minimize the operating costs for their transport authority and private company end users who often run a large number of vehicles over many years.

One solution to the challenge of fuel efficiency that is becoming ever more popular in the transportation industry is to minimize the weight of the components and structures within the vehicle. Lighter vehicles require less energy to move and can retain the desired performance characteristics while making use of a lighter, smaller, less polluting engine.

NEPTECH (New Product Technology Center) is an autonomous institution under Vietnam’s Department of Science and Technology. Its role is to perform scientific research and technology transfer activities into local industry. As part of its research activities, NEPTECH became involved in a development program for a local mass transportation vehicle manufacturer. The client wanted to explore new methods to reduce the weight of the vehicle in an effort to meet its fuel efficiency and cost targets.

NEPTECH approached Altair ProductDesign to assist with the project after seeing the results that Altair had achieved during the development and optimization activities undertaken on its own bus platform, the Altair BUSolutions LCO-140H.
“Altair has successfully demonstrated through simulation studies (gauge optimization) that the weight of a 24 seater intercity bus frame can be reduced by 17%, while maintaining all design and performance characteristics”

Tri Nguyen, Design Manager, NEPTECH

Challenge: Reducing Vehicle Weight Without Sacrificing Performance

Weight reduction in the mass transportation industry can be achieved through two primary methods. Firstly, the materials used in the bus can be substituted for lighter alternatives, for example changing conventional steels to aluminum, plastics or even composite materials. Secondly, the vehicle itself can be redesigned or ‘optimized’, taking away unnecessary mass and leaving a structure that uses a minimum amount of material while still meeting all performance criteria such as stiffness and safety standards.

The objective of the project was to reduce the weight of bus structure without impacting passenger safety. The final design of the structure had to meet 'ECE R66', a set of standards which dictates that the superstructure of any oversized vehicle should have enough strength to avoid large deformations during a rollover event. If failed, the deformed frame could intrude into the passenger space causing injury.

Solution: Optimizing the Bus Frame

With the structure of the vehicle roughly defined, the Altair ProductDesign team was able to construct a finite element (FE) model of the frame members ready for optimization. After an initial research period, it was decided that the most effective way to deliver a weight saving was to adjust the thickness of the steel frame, saving weight and material wherever it could be safely removed. In order to identify where the thickness of the frame could be altered, Altair conducted a 'gauge optimization' study.

"The Altair team was free to make adjustments to the thickness of the vehicle's steel frame, saving weight and material wherever it could be safely removed."

The first step in this process was a target setting task based on the desired performance of the bus. These targets included:

- Safety Analysis During Rollover
- Torsion Stiffness Frequency of the Bus Frame
• **Torsional Stiffness Evaluation**  
  When the wheels experience a bump or pot hole and are even in cornering

• **Bending Stiffness Evaluation**  
  Supporting the loads of the passengers, seats and all other mountings

• **Natural Frequency Extraction**  
  Vibrations levels which can result in issues of comfort and acoustic problems

With these targets set, Altair ProductDesign's vehicle development experts were able to conduct the optimization study. The team were provided with a range of predetermined forces and loads which are exerted onto the vehicle during a variety of use conditions. In addition, a number of design constraints were identified; non-designable spaces in the structure where the frame could not be altered such as the door location, chassis mounting plates, floor back and seat frame and the box frame.

The Altair team used OptiStruct, the design optimization technology from within Altair's HyperWorks suite of simulation solutions to conduct the gauge optimization study.

Once the optimized design had been produced and reviewed by the engineering team, inertia relief analysis could be used to validate the new design. Standard G loads were applied to both the baseline and optimized designs to extract the forces experienced at the tire locations.

The FE model with all the added weights and mountings was considered for the validation of the design. The load case for the inertia relief case included braking, cornering and acceleration.

**Result: Achieving a 17% Reduction in Overall Vehicle Weight**

The baseline design was successfully optimized for weight based on gauge optimization. The weight of the frame was reduced by 17% while maintaining all design and performance characteristics.

Torsional stiffness was slightly reduced but remained well above the requirements for a mini transportation bus frame. Frequency characteristics were improved compared to the baseline design.

For rollover analysis, as per the ECE R66 standards, both the baseline and optimized designs are ‘stable’ at 30 degrees. In addition, the intrusion numerical values were successfully kept low when considering the overall dimensions of the bus in the optimized model.

By successfully reducing the weight of the frame through the use of gauge optimization on the vehicle's frame, NEPTECH's bus manufacturer client can be confident that the new design will help to minimize fuel consumption and CO2 emissions.

Find out more about Altair ProductDesign at: [www.altairproductdesign.com](http://www.altairproductdesign.com)

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About Altair

Altair empowers client innovation and decision-making through technology that optimizes the analysis, management and visualization of business and engineering information. Privately held with more than 1,800 employees, Altair has offices throughout North America, South America, Europe and Asia/Pacific. With a 25-year-plus track record for innovative product design and development, advanced engineering software and grid computing technologies, Altair has more than 3,500 corporate clients representing the automotive, aerospace, government and defense, and consumer products verticals. Altair also has a growing client presence in the life sciences, financial services and energy markets.

Altair ProductDesign is a global, multi-disciplinary product development consultancy of more than 700 designers, engineers, scientists, and creative thinkers. As a wholly owned subsidiary of Altair Engineering Inc., this organization is best known for its market leadership in combining its engineering expertise with computer aided engineering (CAE) technology to deliver innovation and automate processes. Altair ProductDesign firmly advocates a user-centered, team-based design approach, and utilizes proprietary simulation and optimization technologies (such as Altair HyperWorks) to help clients bring innovative, profitable products to market on a tighter, more efficient time-scale.

HyperWorks is an enterprise simulation solution for rapid design exploration and decision-making. As one of the most comprehensive, open-architecture CAE solutions in the industry, HyperWorks includes best-in-class modeling, analysis, visualization and data management solutions for linear, nonlinear, structural optimization, fluid-structure interaction, and multi-body dynamics applications.

Altair Engineering, Inc., World Headquarters: 1820 E. Big Beaver Rd., Troy, MI 48083-2031 USA
Phone: +1.248.614.2400 • Fax: +1.248.614.2411 • www.altair.com • info@altair.com

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