L&L Products®

Accelerating Structural Reinforcement Development Through Digital Engineering, Automation and AI.

How L&L Products Is Reducing the Time Required to Reach a Confident Engineering Decision-A Technical Review of L&L Products' Journey Toward Predictive Engineering

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ABSTRACT

As vehicle development programs become increasingly complex, engineers are expected to evaluate more design concepts while meeting demanding targets for crashworthiness, stiffness, durability, mass reduction, manufacturability, and cost. While finite element analysis (FEA) remains a critical development tool, the number of possible design iterations often exceeds what can realistically be assessed within a typical program schedule.

This paper examines L&L Products' use of digital engineering methodologies—including simulation, optimization, design exploration, automation, and PhysicsAI—to accelerate structural reinforcement development. The work focuses on how historical simulation knowledge can be leveraged to support faster concept evaluation while maintaining engineering confidence.

01. THE ENGINEERING SPEED CHALLENGE

The automotive industry continues to reduce development timelines while simultaneously increasing vehicle complexity. Lightweight architectures, electrification, crash requirements, durability targets, and manufacturing constraints must all be addressed during the design phase.

Finite Element Analysis significantly reduced the dependence on physical testing by enabling structural performance to be evaluated virtually. However, as simulation capabilities improve, a new limitation emerges. Engineers are no longer constrained by their ability to perform analysis, but by the number of design alternatives that could be investigated within available development time.

This challenge raises an important question: Can historical simulation knowledge be leveraged to accelerate future engineering decisions? Can the engineering-time be focused on analysis, instead of launching iterations?

02. STRUCTURAL REINFORCEMENT DEVELOPMENT AS AN ENGINEERING CHALLENGE

Structural reinforcement development provides an ideal environment for exploring advanced digital engineering methodologies because it combines multiple competing objectives within a single design space. Crash performance, durability, stiffness, mass reduction, packaging constraints, manufacturing requirements, and cost targets must all be considered simultaneously. Changes in geometry, material distribution, carrier architecture, or attachment strategy can significantly influence overall vehicle performance as well as cost and manufacturing requirements.

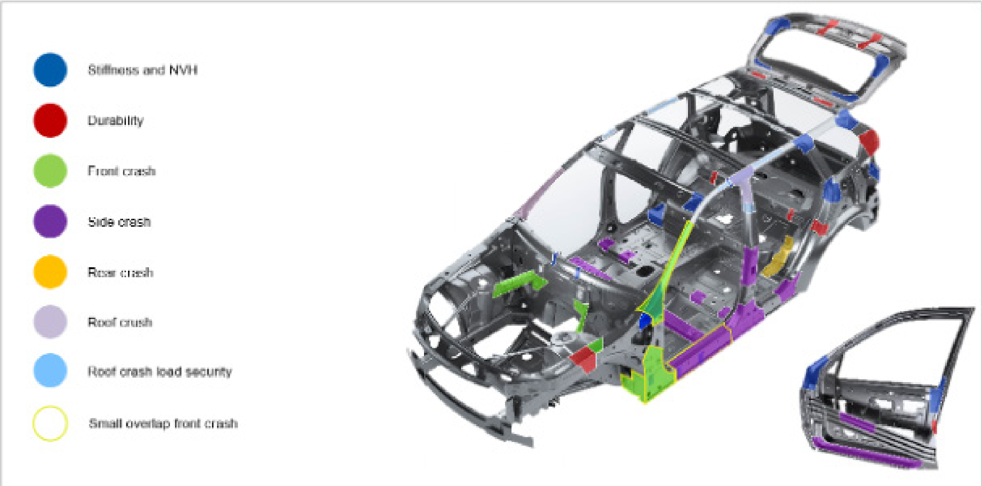


Image 1. *Examples of L&L Products's CBS™ Serial Application Areas*

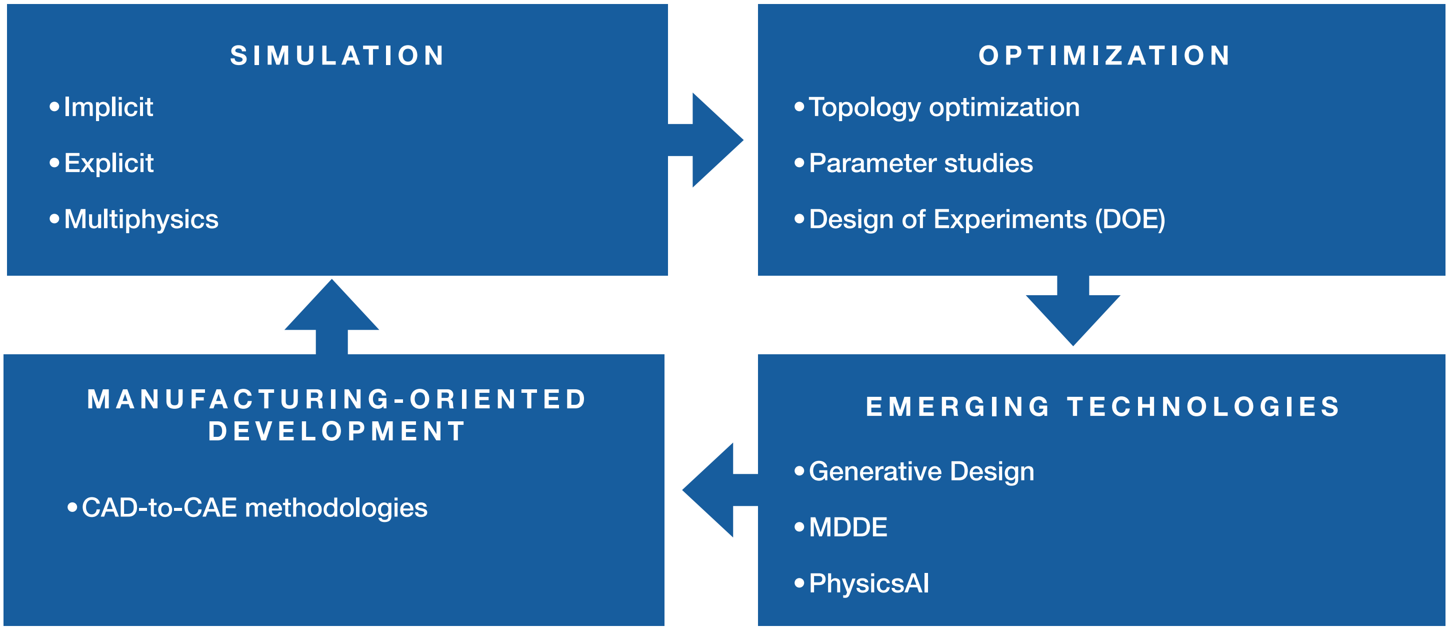
Because every vehicle architecture presents unique requirements, structural reinforcement development generates significant quantities of simulation data and engineering knowledge. This makes it an ideal candidate for optimization, automation, and predictive engineering methodologies.

03. BUILDING A DIGITAL ENGINEERING ECOSYSTEM

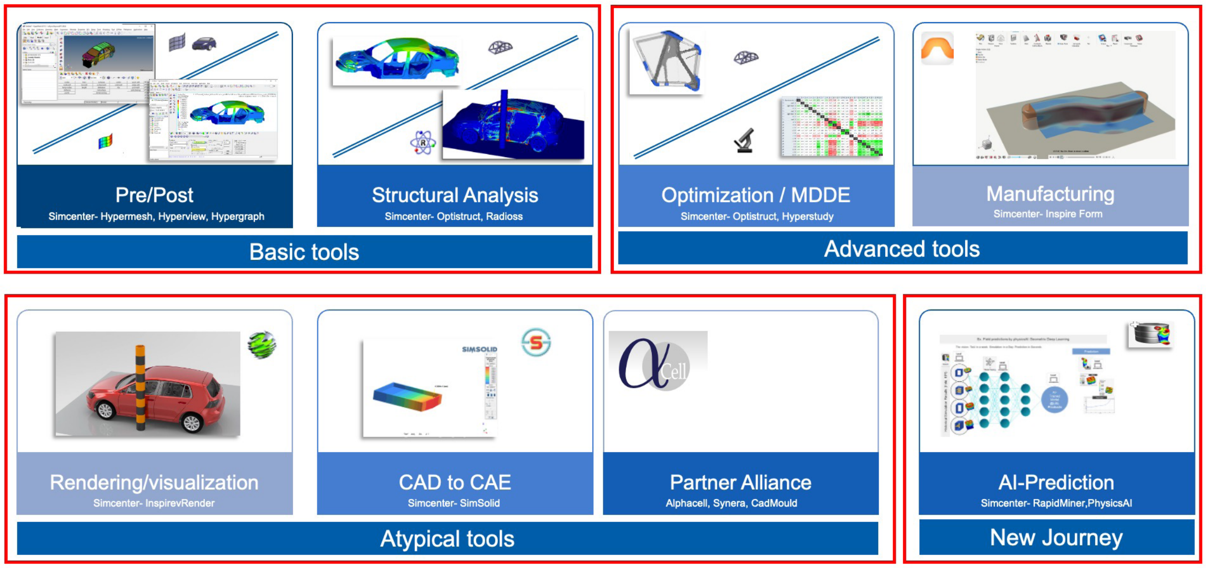
As product complexity increased, the need to evaluate larger design spaces became increasingly important. Traditional simulation workflows provided highly accurate insights but remained dependent on engineering resources and computation time.

To improve development efficiency, L&L Products progressively expanded its use of digital engineering technologies and software packages. What began as a traditional CAE workflow evolved into an integrated engineering ecosystem incorporating simulation, optimization, automation, design exploration, visualization, and predictive technologies.

Capabilities expanded from conventional pre-processing, meshing, solving, and post-processing into a broader environment that combined: Structural analysis, Topology optimization, Design of Experiments (DOE), Multidisciplinary Design Exploration (MDDE), Manufacturing-focused simulation, Visualization and rendering, and AI-enabled prediction.



This evolution transformed simulation from a verification activity into a strategic decision-support capability. Engineers were no longer focused solely on evaluating individual design concepts but on understanding the broader relationships between design variables, performance outcomes, and development constraints.



04. FROM SIMULATION TO ENGINEERING KNOWLEDGE

As optimization studies and design exploration activities expanded, increasing amounts of engineering data became available.

Rather than evaluating individual designs independently, engineers gained access to large datasets describing relationships between geometry, material distribution, and structural behavior. These datasets revealed patterns and performance trends across entire design spaces.

As simulation databases continued to grow, a new possibility emerged: Could existing simulation knowledge be reused to evaluate future concepts before a new simulation is executed?

This question marked the beginning of L&L Products' exploration of predictive engineering.

05. ENTERING THE ERA OF PREDICTIVE ENGINEERING

Predictive engineering seeks to learn relationships between design inputs and performance outputs using historical engineering data.

Siemens Simcenter PhysicsAI was selected as the framework for this investigation because it enables predictive models to be developed directly from existing CAE datasets. Geometry information, simulation results, and engineering performance indicators can be used to train models capable of estimating performance for previously unseen designs.

The objective was not to replace simulation, but to determine whether accumulated engineering knowledge could be leveraged to accelerate concept evaluation and early-stage design exploration.

This introduced a new engineering paradigm: Test in a week, Simulate in a Day, Predict in seconds.

For engineering teams facing increasingly complex product development challenges, this paradigm represents a significant opportunity to accelerate decision-making while maintaining confidence in engineering outcomes.

06. THE REAL CHALLENGE: PREPARING ENGINEERING KNOWLEDGE FOR PREDICTION

One of the most important discoveries made during this work was that predictive engineering is fundamentally a data challenge.

While considerable attention is often given to AI models and algorithms, the quality of predictive results depends heavily on the quality, consistency, and structure of the underlying engineering data.

Developing useful predictive models required:

- Data preparation
- Dataset curation
- Outlier analysis
- Model validation
- Structured engineering workflows

In practice, preparing engineering knowledge for AI consumption often required more effort than training the models themselves.

Prediction quality was strongly influenced by factors such as dataset diversity, training volume, input consistency, and traceability of engineering results.

These findings reinforced a simple but critical principle: it all starts with data and data quality.

DATA PREP AND CURATION →

- Explore and analyze datasets to ensure readiness for model development
- Ensure that the input models are valid finite element models or results that can be used in HyperWorks.
- Convert Excel files to JSON format for processing
- Maintain high data quality standards to optimize model performance

DATASET CREATION →

- Create data structures fitted to models
- Create multiple datasets with varying numbers of variants.
- Outlier detection and analysis.

MODEL DEVELOPMENT →

- Train models
- Tune
- Hyperparameters
- Analyze error
- Metrics

MODEL VALIDATION

- Test model on the new data

07. CASE STUDIES IN PHYSICSAI IMPLEMENTATION

Geometry-Based Prediction

The first study investigated whether historical structural simulation results could be used to predict the performance of previously unseen geometries.

The resulting models demonstrated significant reductions in concept evaluation time while maintaining good correlation with conventional simulation results. This approach enabled faster concept screening and increased design space exploration.

The study also highlighted the importance of geometry representation, model generalization, and continuous validation.

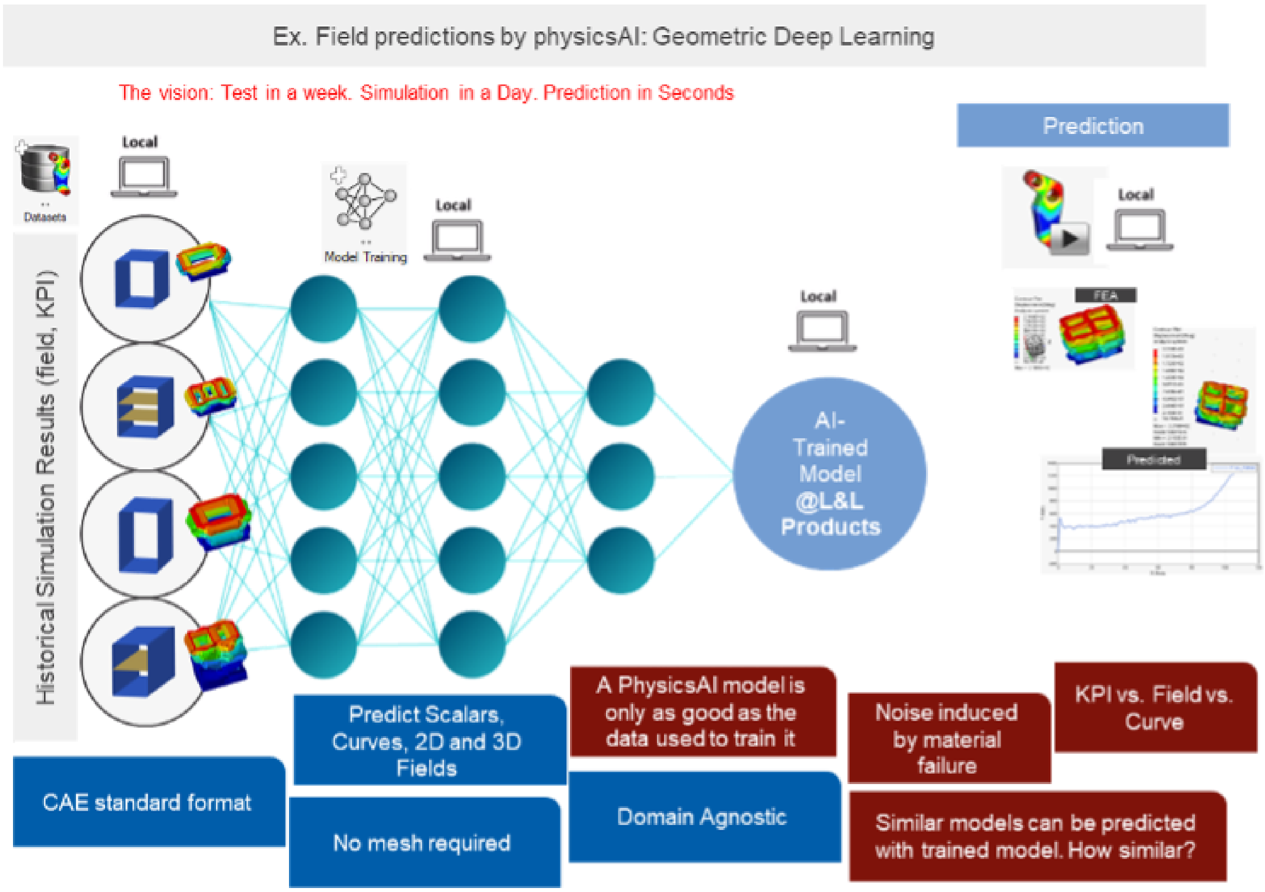
KPI-Based Prediction

A second study explored whether engineering Key Performance Indicators (KPIs) could be predicted using historical project information.

The results demonstrated that prediction quality improved significantly when richer engineering information was included within the training dataset. Conversely, simplified datasets frequently resulted in underfitting and reduced predictive capability.

A key lesson emerged from this work:

Prediction accuracy was influenced as much by dataset quality as by model selection.



09. LESSONS LEARNED AND FUTURE OUTLOOK

Several practical lessons emerged from this work.

- First, predictive engineering begins with data quality. Successful model development depends on structured, traceable, and representative engineering data.
- Second, automation and design exploration methodologies provide a mechanism for generating engineering knowledge at scale.
- Third, predictive models complement engineering expertise rather than replace it. Engineering judgment remains essential for data preparation, model validation, and interpretation of results.
- Finally, predictive engineering should be viewed as an extension of established engineering practices rather than a replacement for simulation.

The work presented here demonstrates how simulation, optimization, automation, and PhysicsAI can be combined within a unified development workflow to accelerate concept evaluation.

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Núria Ignés i Mullol holds a degree in Mechanical Engineering with a specialization in Materials Science from the Universitat Politècnica de Catalunya (UPC), Barcelona.

After seven years in the automotive industry specializing in CAE, Moldflow analysis, and structural simulation of plastic components, she joined L&L Products Europe in 2009.

Today, she leads the development of L&L Products' Reinforce portfolio in Europe, overseeing CAE activities and the design of structural reinforcement solutions for body-in-white, battery, and chassis applications. Her work focuses on simulation-driven development, optimization methodologies, and emerging digital engineering technologies that accelerate product development and support engineering decision-making.

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