# A REVIEW OF FEA TECHNOLOGY ISSUES CONFRONTING THE AUTOMOTIVE INDUSTRY

*Fernando Espiga, LABEIN-TECNALIA, Bizkaia, Spain*
*Peter Segaert, LMS International, Leuven, Belgium*

## SUMMARY

Major issues related to the uptake of FE technology in automotive industry are identified. Regarding durability and fatigue, the treatment of joints, welds and bonding are a priority. Increasing complexity of automotive systems makes the interaction between different design domains a relevant issue in multiphysics analysis as well as analysis technologies like contact, automatic and adaptive meshing and simulation of as-assembled models. The importance of new materials in design solutions involves that material modelling becomes a priority together with the simulation of manufacturing processes. Finally, with regard to dissemination and training issues, there is a need of standards and recommended practices since smaller organisations are not ready to deploy the technology as needed to support the trend to transfer design competences towards the supplier.

## 1: BUSINESS DRIVERS

The driving forces leading the automotive change are the key factors determining the changes happening in design & analysis technology. The pressure on costs involves time-to-market and time-to-manufacturing reduction with higher quality levels. Developing times are expected to be reduced up to 18 months by 2010 from current 30 months. The emphasis on reductions in costs and lead-time gives rise to a more effective integration of development resources into the product and process design phase through practices such as concurrent engineering, partnership sourcing…

Ongoing innovation demand is driven by different factors:

- customer requirements focused on comfort, safety and personalisation. This is leading to a change in the design content of a car with the biggest impact in the portion of electronics, telematics and software which is estimated to reach 35% in 2.015 from 22% in 2.002. Serviceability and reliability are becoming more and more relevant from the customer view.
- legislation and commitment for environmental protection puts the emphasis on reduction in weight and consumption

Very relevant changes are also found on the side of organisational issues and business models: there is a shifting of the supply chain towards the customer in such a way that the value added by component suppliers rises. Design responsibility is increasingly transferred to the supplier.

Thus, in this effort to meet customer and society demands, the European automotive industry and its suppliers face the challenge of continuously providing more value and quality at no price increase. Modelling & Analysis technology must contribute this aim.

Complexity in product design is increasing due to the need to deal with interaction among different design domains, integration of components and functions, new materials and multi-material solutions, emerging manufacturing processes and incorporation of electronics, telematics and software.

## 2: INDUSTRY SECTOR REQUIREMENTS

The requirements and needs of the automotive sector are derived from information collected in various workshops held in the context of FENET network project as well as other technical seminars and conferences.

Apart from identifying and defining the engineering analysis requirements and their associated methods and tools with relevant priority levels, it is also essential to indicate the functional and industrial maturity of each. The maturity level is necessary to assess whether a given method / tool at the specified level of maturity could be of interest for application in their own domain or to get an idea about how much additional development would be needed before the method / tool would suit their needs. The objective is to provide a means to distinguish between methods and tools ranging from ‘a wish list of ideas and concepts’ to fully validated, robust, integrated CAE applications. The requirements are grouped according to these four technology areas:

- Durability & Life Extension
- Product & System Optimisation
- Multi Physics & Analysis Technology
- Education & Dissemination

Three indexes are used to define the position of every requirement: firstly the technological readiness level (TRL) indicating the state of the art or technological maturity, secondly the state of practise (SoP) giving a measure of industrial maturity and lastly, the priority level index (PLI) which points at the relevance for industry. All these indexes range between 0 (lowest) and 9 (highest).

## 3: DURABILITY AND LIFE EXTENSION (DLE)

Durability and Fatigue continue in the forefront of awareness driven by serviceability and reliability issues. It is crucial to ensure that a system remains functional throughout its intended lifecycle, avoiding warranty costs and large damage claims. The treatment of joints, welds and bonding, are placed on the first level of priority. Figure 1 shows the technological maturity represented versus the industrial maturity (TRL vs. SoP) for every considered item. The symbol size indicates the priority level (PLI) as given by industrial need.

| Item | Modelling / analysis requirement |
|---|---|
| LT.DLE.1 | Composite materials characterisation (material data base) |
| LT.DLE.2 | Fracture mechanics, crack grow and assessment and residual strength prediction (adaptive mesh) |
| LT.DLE.3 | Fatigue life prediction & assessment |
| LT.DLE.4 | Damage/deterioration modelling and assessment |
| LT.DLE.5 | Reliability and probabilistic analyses |
| LT.DLE.6 | Creep and related time-dependent phenomena |
| LT.DLE.7 | Buckling and post-buckling |
| LT.DLE.8 | Modelling and assessment of residual stresses (due to welding, moulding,casting etc) |
| LT.DLE.9 | Modelling and assessment of bonding |
| LT.DLE.10 | Modelling and assessment of welds |

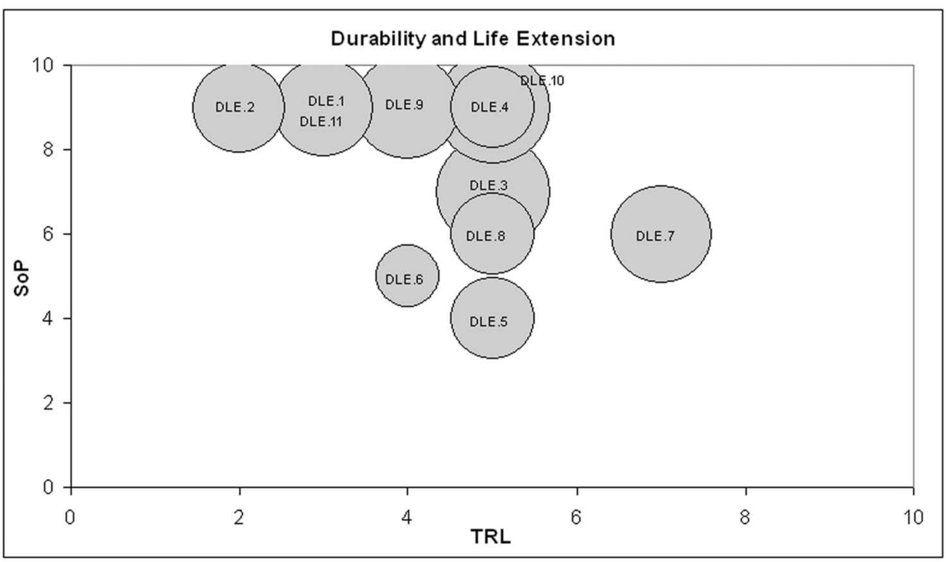


*Figure 1: Durability and Life Extension: technological maturity (TRL), industrial maturity (SoP) and priority level (PLI)*

## 4: PRODUCT & SYSTEM OPTIMISATION (PSO)

Multi-objective and multidisciplinary optimisation are taking increasing relevance due to the fact that automotive system design is becoming more and more complex. It has to deal with the challenge of integrating more components and functions, involves the interaction between different design domains (mechanical, fluids, electronics, telematics…) and requires evaluating the impacts and interactions between the manufacturing, use and recycling phases of the vehicle life cycle. A crucial competitive factor is how well modelling and simulation is integrated in the overall processes overcoming the conflict of building models and incorporating the results into the development process. Representation of technological versus industrial maturity together with priority level for the whole set of items is given in figure 2.

| Item | Modelling / analysis requirement |
|---|---|
| LT.PSO.1 | Linear multidisciplinary optimisation (structural) |
| LT.PSO.2 | Non linear multidisciplinary optimisation |
| LT.PSO.3 | Linear/non linear multi-objective optimisation (mat, thick) |
| LT.PSO.4 | Linear/non linear multi-objective optimisation (shape) |
| LT.PSO.5 | Less memory consuming codes |
| LT.PSO.6 | Use of general purpose optimisation tools for “non-FE” models |
| LT.PSO.7 | Use of decision support tools for management issues |
| LT.PSO.8 | Use of decision support tools for design issues |

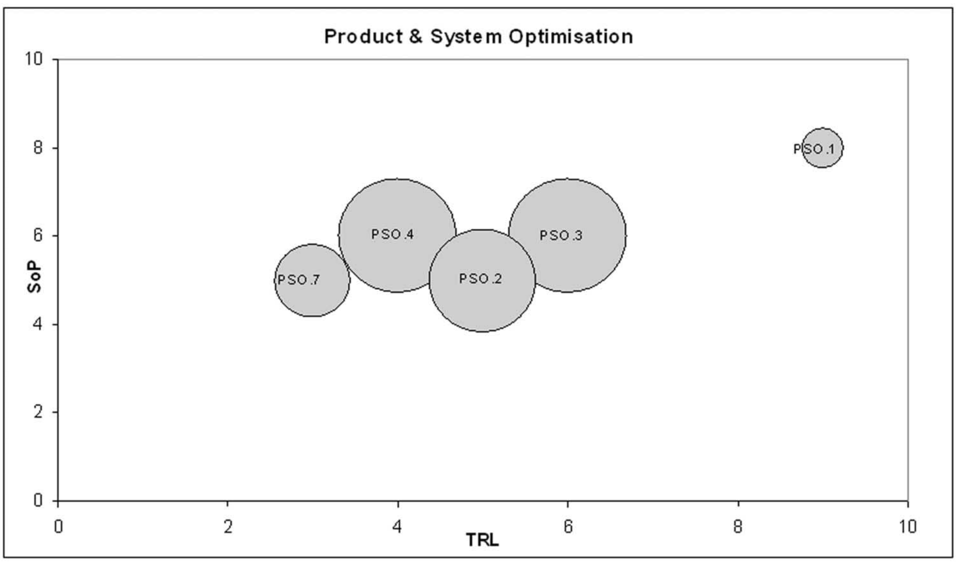


*Figure 2: Product & System Optimisation: technological maturity (TRL), industrial maturity (SoP) and priority level (PLI)*

## 5: MULTI PHYSICS & ANALYSIS TECHNOLOGY (MPT)

Complexity in product design makes that analysis and design have to look at complex assemblies rather than isolated components. The high priority given to analysis technologies like contact, automatic and adaptive meshing, simulation of as-assembled models confirms this trend. The complexity of modelling some physical phenomena as well as multiphysics processes demands an intimate understanding of the mechanics and physics behind the system.

On the other hand, the massive use of electronics, telematics and software in automotive systems makes much interest be focused on methods enabling engineers to identify and resolve issues across electrical and mechanical domains, shifting the emphasis towards multiphysics analysis.

In addition to this, increasing design solutions based on new materials give rises to consider material modelling as a priority. ERTRAC (European Road Transport Research Advisory Council) estimates that the majority of product and process innovations will be based on improved or newly developed materials in the next one to two decades leading to a situation where the capability to accurately model the behaviour of new materials is vital for successful evolution and revolution of vehicles and road transport infrastructure.

Simulation of manufacturing processes is also perceived as a very relevant issue in analysis technology (as manufactured models, joining, welding, casting...). These results are consistent with the view expressed by EUCAR (European Council for Automotive R&D) which identify 2 major cross-functional technology vectors: smart use of conventional and new materials and flexible manufacturing with focus on IT support and modelling simulation of manufacturing processes. Representation of technological versus industrial maturity together with priority level for the set of items is given in figure 3.

| Item | Modelling / analysis requirement |
|---|---|
| LT.MPT.1 | Multi disciplinary robust design |
| LT.MPT.2 | As manufactured models |
| LT.MPT.3 | As assembled models |
| LT.MPT.4 | Product virtual assessment |
| LT.MPT.5 | Standard to link highly specialised codes |
| LT.MPT.6 | Structure - compressible fluid interaction |
| LT.MPT.7 | Structure - incompressible fluid interaction |
| LT.MPT.8 | Coupled analyses for structure/ aero-elastics/ aerodynamics/ acoustics |
| LT.MPT.9 | Thermo-mechanical interaction and thermo-elastic deformation |
| LT.MPT.10 | Structure – aerodynamics, thermodynamics interaction |
| LT.MPT.11 | Structure - aero-thermodynamics - chemical interaction |
| LT.MPT.12 | Structure - optics interaction |
| LT.MPT.13 | Structure / wave antenna interaction |
| LT.MPT.14 | Structure / kinematics / control logic |
| LT.MPT.15 | Coupled fluid structure interaction for biomechanical devices |
| LT.MPT.16 | Magnetic hydrodynamics |
| LT.MPT.17 | Thermo-mechanical and Magnetic interaction |
| LT.MPT.18 | Electro-Magnetic and thermo-mechanical interaction |
| LT.MPT.19 | Multi-scale analysis |
| LT.MPT.20 | Micro-Macro scale thermal/thermo-mechanical analysis |

| | |
|---|---|
| LT.MPT.21 | Sheet & plate metal forming |
| LT.MPT.22 | Forging |
| LT.MPT.23 | Casting |
| LT.MPT.24 | Moulding |
| LT.MPT.25 | Extrusion |
| LT.MPT.26 | Joining |
| LT.MPT.27 | Welding Processes |
| LT.MPT.28 | Heat treatment processes |
| LT.MPT.29 | Contact Analysis |
| LT.MPT.30 | Dynamic (near-) real-time mathematical model test correlation/update |
| LT.MPT.31 | Support for materials, with respect to Physical Representation |
| LT.MPT.32 | Support for materials, with respect to Failure and damage criteria |
| LT.MPT.33 | Support for materials, with respect to Links to design tools |
| LT.MPT.34 | Support for materials, with respect to Micro-mechanics / multi-scale analysis |
| LT.MPT.35 | Tools for software parallelisation |
| LT.MPT.36 | Less memory-intensive codes |
| LT.MPT.37 | Integration of virtual reality tools & FE |
| LT.MPT.38 | Specific software for coupling FEA with other techniques |

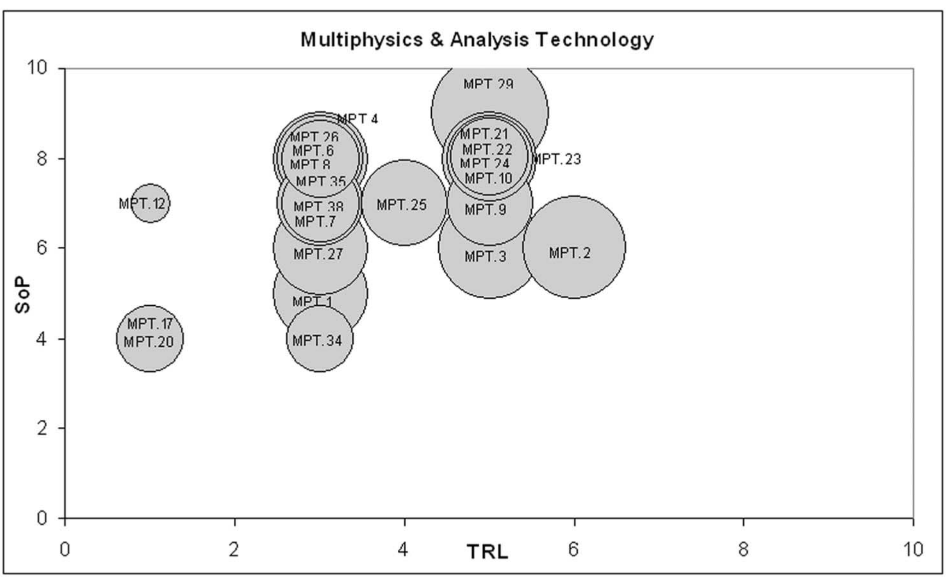


*Figure 3: Multiphysics & Analysis Technology: technological maturity (TRL), industrial maturity (SoP) and priority level (PLI)*

## 6: EDUCATION & DISSEMINATION

Leading-edge research needs to be powered by a closer cooperation among all the involved agents of industry and academia driven by the car manufacturers. But design is increasingly done by suppliers leading to a shifting of analysis competences downwards in the supply chain. This fact is behind the high priority given to dissemination and training issues. Moreover, the training requirements of modellers will increase as their importance within the design and development process rises. Smaller organisations are not ready to deploy the technology as needed to support the trend to transfer design responsibility to the suppliers. The lack of standards or recommended practices regarding the use of FEA in design does not help a rapid diffusion of simulation technology. There is a need of standard analysis procedures which can be adopted through the supply chain.

A high priority level is assigned to diffuse the simulation mentality within the industry through the training of tomorrow designers. Regarding leading-edge research in modelling, there is a need for increased focus and improved co-operation between industry and academia.

The decision by the manufacturers to move the development of components and systems to the suppliers adds a constraint on modelling and simulation. A disconnect is created between manufacturers working on vehicle integration models and suppliers working on subsystems models. The challenge for suppliers is to develop the staff and expertise to take over some of the subsystem modelling that goes into designing their component or system. One of the industry barriers to uptake modelling and simulation technologies is the production. Sometimes it happens that short-minded management focuses too much on “today” production problems and emergencies and it is not able to plan on 5-10 years basis. This fact is very dangerous not only from the “FEM” side of view, but also in terms of company survival in the competitors’ sea.

A company that decides to uptake modelling methodologies needs more than one year to choose hardware and software, to find new employees and to train them: for production weighted down people it may looks a very long time. Within the workers old generation sometimes there is an odd suspicion that modelling and simulations are only nice coloured maps, good only for hanging them to the walls, instead of being very useful for designers.

## 7: CONCLUSIONS AND FUTURE WORK

The more stringent requirements of car industry for the end product and manufacturing process, the encouraging product innovation and use of new materials, the greater demand for lightweight concepts and the acceleration of time to the market are paving the way for a future scenario characterised by an intensive use of simulation technology from concept through to production. The development process requires the integration of design, experimental testing and simulation.

Specific technologies to focus the developing, dissemination and training efforts are:

- NVH (noise, vibration and harshness) is a key issue in today analysis demanding rapid development and adoption of new technological advances in simulation methods (in particular acoustics). Very important factors for marketing a new vehicle are nowadays comfort and sound quality which, until now, could not be simulated

- Durability and Fatigue demand simulation methods dealing with integrated and multi-scale approaches: from the local level where essential fatigue characteristics are derived up to the global level dominated by the vehicle dynamics.
- Safety demand has so far placed the emphasis on “crashworthiness”. Design for minimising pedestrian and occupant injures are receiving increasing attention. There is a need of model validation techniques (how to validate the model) and guidance on realistic scenarios (what to model).
- Emerging requirements: occupant comfort, visibility under extreme conditions, interior air flow, reduction of acoustic sources, thermal distribution...
- Multi-level modelling strategies: the design of automotive systems requires a multitude of single components, subsystems and complete system analyses. Each analysis requires models at different modelling levels properly linked
- Simulation of manufacturing processes with a wider perspective, including aspects like flow of materials and products, scheduling, logistics, lay-out, ergonomy, safety at the work place. Product performance analysis by including manufacturing-induced effects.

Increasing role of component suppliers in product development requires all the participants in the supply chain to engage in building organisational competences for collaborative design. Simulation technology will have to face this issue through development of tools and analysis methodologies able to operate in distributed design environments managed by complex network organisations.

## REFERENCES

- FENET project deliverable D2312. Land Transport Industry Sector Requirements. 2005

- ERTRAC, European Road Transport Research Advisory Council. Strategic Research Agenda. Draft Version 3.5. December 2004

- EUCAR, Directions of research and development towards clean, safe and efficient mobility and transport - a proposal on the future automotive and road transport R&D in Europe, European Council for Automotive R&D, December 2000

- Foresight Vehicle Technology Roadmap: Technology and Research Directions for Future Road Vehicles. Foresight UK. 2004

- Automobile Technology 2010. HypoVereinsbank and Mercer Management Consulting. 2001