Investigation of Standardization Practices for a Responsible Use of Computational models in Engineering (**SPRUCE**)

MODPROD2020, Linköping

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Outline

- RISE overview
- SPRUCE project
  - Background and motivation
  - SPRUCE survey
- Future work

RISE overview

Applied Research and Development

- Research and Innovation projects
- Expert consultation
- Service design and design processes
- Innovation support for SMEs

Industrialisation and Verification

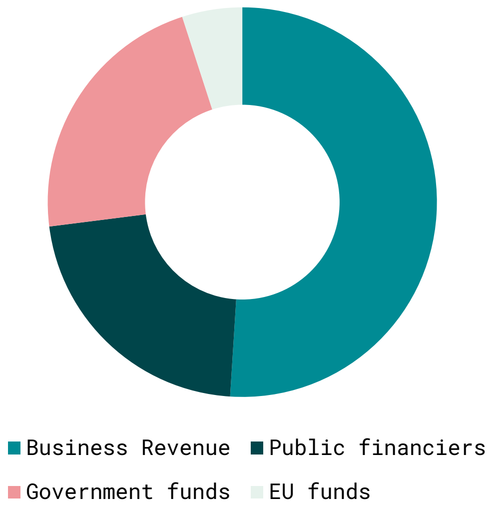
- Testbeds and demonstration facilities
- Technical assessments and verification
- Prototypes and pilot line production

Quality Assurance

- Certification

Turnover distribution RISE group

3 066 MSEK (2018)



RISE – Applied Mechanics

In a nutshell

- Department within the Division of Material&Production.
- Researchers, engineers, technicians, administrative staff ~50 employees (Borås & Gothenburg).
- Central node for solid and structural mechanics at RISE.
- Core business in ***standardized structural testing*** for the fulfilment of certification requirements of e.g. products for road safety, personal safety, construction elements and materials (CE). Active in standardization committees.
- Large experimental & simulation capabilities. Research focus on structural and material mechanics, ***reliability***, ***model validation***, ***uncertainty quantification***.
- Clients in several industrial sectors (e.g., construction industry & infrastructure, automotive, energy)

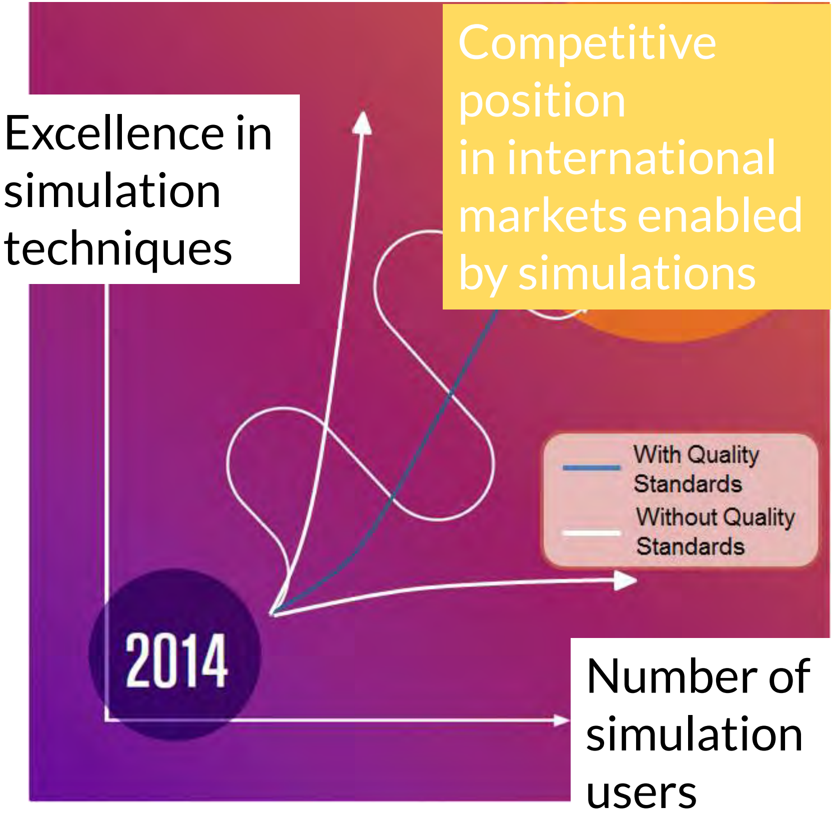
Example of load frame for material testing

Max force 1.2 MN

SPRUCE project

Background/Motivation

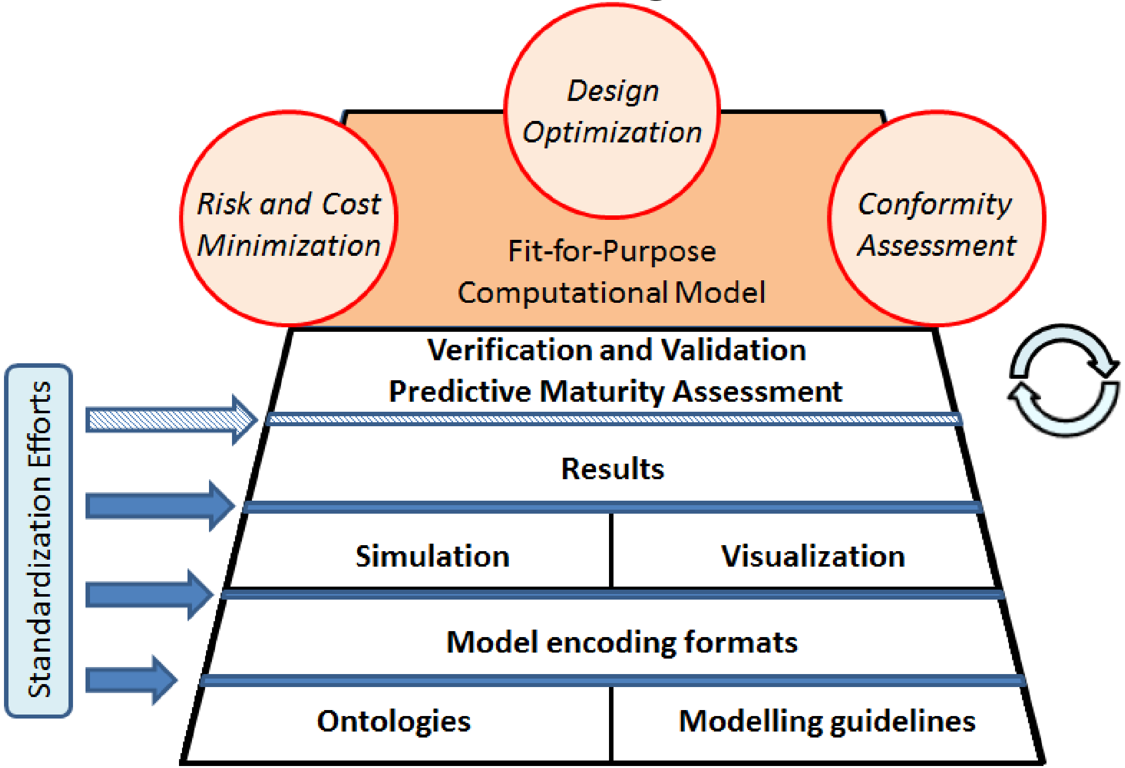
- Growing adoption and complexity of numerical simulations in product development and decision-making processes.
- Quality control and certification rely on standards to ensure reliability and safety of products before being introduced on the market. What is a **standard**? (CEN): *it is a technical document designed to be used as a rule, guideline or definition. It is a consensus-built, repeatable way of doing something.*
- Physical testing provides evidence on the safe performance of products. Numerical simulations are gaining acceptance too, but: *how to design models to be as credible as testing methods*?
- Quality standards and guidelines adapted to simulations are available, but to what extent are they actually used in industrial practice?



Virtual Nation Agenda (SWEREA 2014)

Standardization for Numerical Modelling

- Standardization is relevant in many aspects of modelling and simulation
- Existing and emerging standards in MBSE and FEA-based design focus on *interoperability*: FMI/FMU, STEP AP209, VMAP
- Particular attention is devoted to standardized practices for verification and validation as key elements to secure the *fitness for purpose* (alt. *credibility*) of computational models.



NAFEMS resources on Standards and Simulations:

- Standards Iniative (Open catalogue of existing standards
- Webinar on Emerging Standards for MBSE

Standardization for Numerical Modelling

- Standards for data and models exchange which focus on interoperability of software development platforms (e.g. FMI)

Well known challenges (complexity of tools, format, etc.) AND business benefits, e.g.:
- reuse of product data and models (reduced dev time),
- more efficient interaction within company (e.g. engineering ↔manufacturing)
- better product and process control over whole life cycle, etc.

But is that enough to ensure also adequate *credibility* of the models?

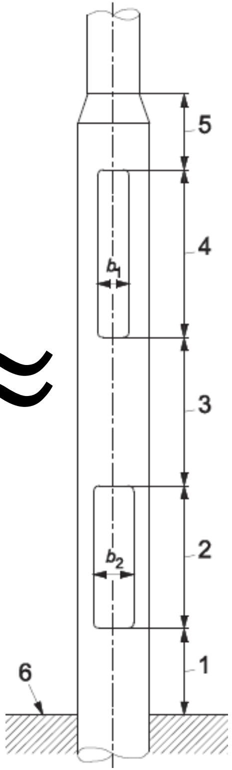
A practical example: lighting poles

SS-EN 40-3-1
Def of loads

SS-EN 40-3-2
Verification
by testing

SS-EN 40-3-3
Verification
by calculation

$\approx$



- Ultimate Limit State (Stress/Strength)

$$\frac{M_x}{M_{ux}} + \frac{M_y}{M_{uy}} + \frac{T_p}{T_u} \leq 1$$

- Serviceability Limit State (Deflection/Classification)

Bending and torsion stress can be evaluated with e.g. FEA, but: mesh density? Element type? Accuracy requirements?

Standardization for Numerical Modelling

Why bother? What can go wrong?

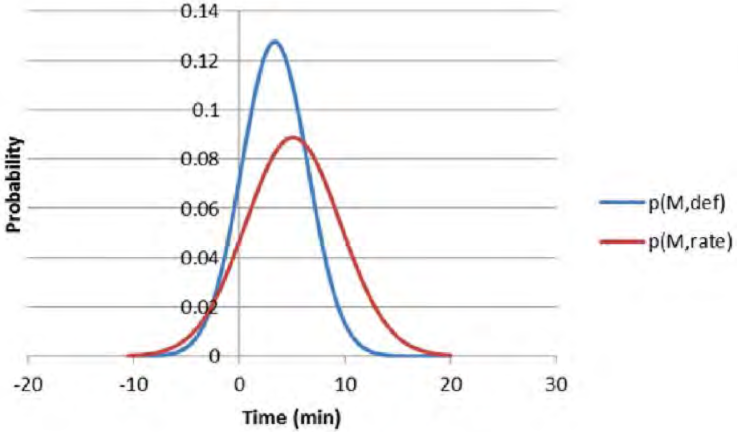
Fire Safety Journal 92 (2017) 64–76

A round robin study on modelling the fire resistance of a loaded steel beam

David Lange *, Lars Boström

RISE Research Institutes of Sweden, Safety and Transport/Fire Research, Sweden

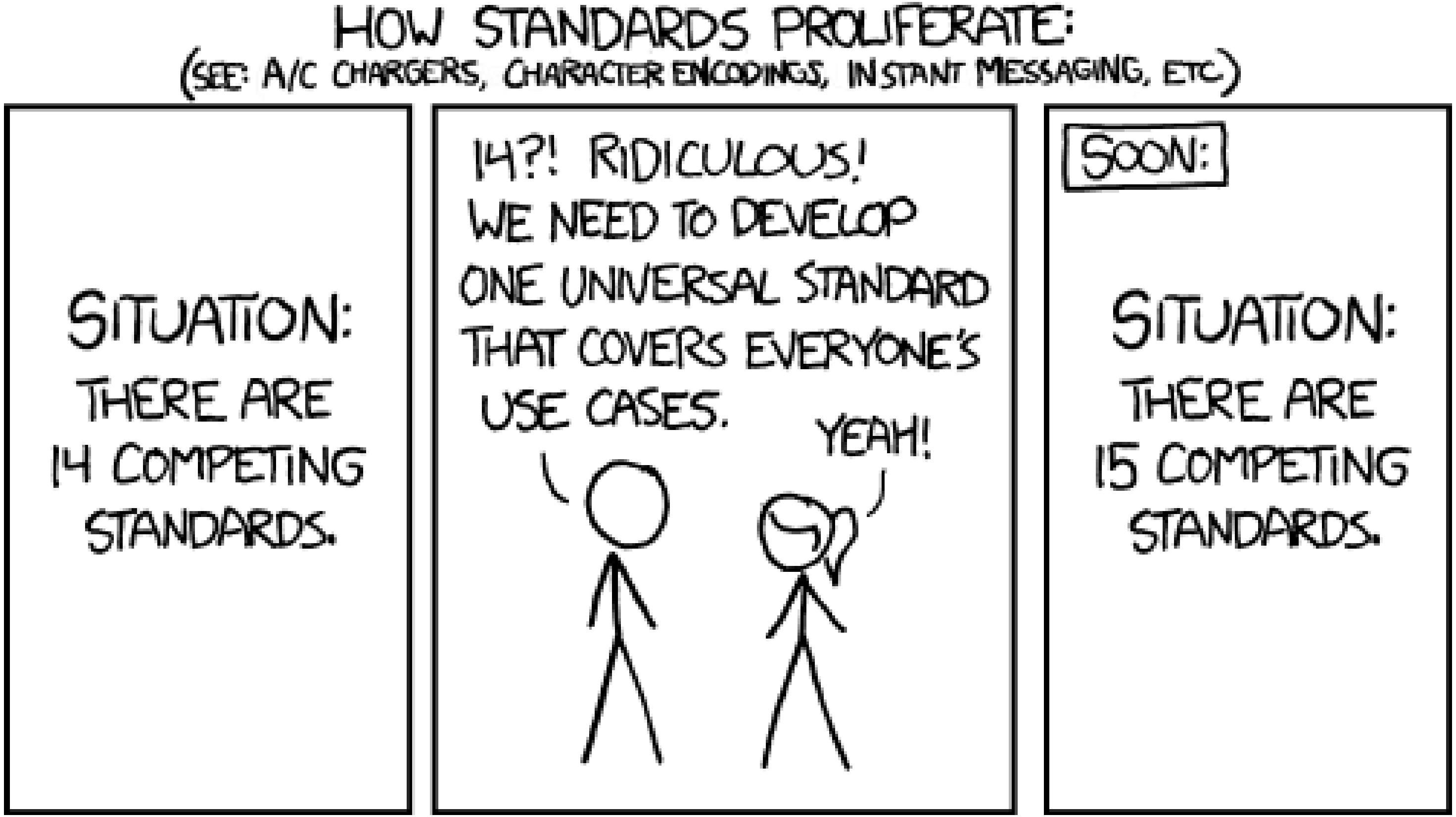
[...] calculations or simulations are now often used as an alternative means of evaluation of structures exposed to fire compared with testing. For building elements and structures in Europe the Eurocodes are the basis for design, and these allow calculations in simple or advanced design methods. For certification of certain building products calculations have the same credibility as testing. However, while for testing there are requirements on accreditation of the test laboratory as well as follow up inspections, this is not the case for calculations. In other words, when evaluating building products for certification based on testing there is a formal control system that must be followed. This type of control does not exist when doing the same job based on calculations.



$M \sim T - C$ (Prediction by Test – Prediction by Calculations)

Prob($M < 0 \equiv$ unsafe calculation) ≈13%

Project scope and goals



https://xkcd.com/927/

SPRUCE Project: scope and goals

Scope and limitations

- The project is a feasibility study.
- The focus will be on building a comprehensive picture of the state-of-the-art, to identify critical questions and suggest roadmaps and priorities, but *not* to implement actual solutions.
- The development and testing of novel solutions for specific problems should be addressed in future projects.

Goals

- To analyze the role that standardization can play in designing effective strategies for quality assurance of computational models developed for engineering applications.
- To map out current practices and needs related to quality assurance of computational models for engineering applications.
- To develop a roadmap/ strategy for future work in this area

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Planned activities

WP 1	Project management
RISE	Administrative tasks including economy management and contact with VINNOVA, circulation of information among all partners
WP 2	Mapping of existing standards and current practices for quality assessment of computational models
RISE	Task 2.1 – Literature survey
ALL	Task 2.2 – Collection of information from model developers and users based on formal and informal approaches, e.g. surveys, participation to workshops and technical presentations, networking activities with relevant ongoing or recently completed national and international projects.
WP 3	Strategic vision development
ALL	The outcomes of WP 2 will be analysed and elaborated in order to produce a structured proposal for a common strategic vision about quality standards for computational models.
WP 4	Recommended actions
ALL	A series of concrete actions to achieve the goals set in the strategic vision from WP 3 will be defined, highlighting those which should be prioritized in the closest time horizon (0 – 3 years). Opportunities for future collaboration, expansion of the consortium and related funding questions will be also considered.

External initiatives related to WP2: 1 2 3 4

Time frame:
April 2019 – March 2020

Partners:
RISE (coordinator)
Volvo Cars Corporation
Validus Engineering
FS Dynamics

Budget
1 075 000 sek
79% granted by
VINNOVA
Sweden's Innovation Agency
is gratefully acknowledged

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SPRUCE Survey

- 23 qualitative and quantitative questions divided into 4 sections:
  - Persona and Organisation
  - Process and Methodology
  - Tools and Environment
  - Confidence building and quality appraisal activities
- Data collected during individual interviews
- ~30 respondents from ~15 companies (Automotive 1st)
- No limitations of industrial branch or numerical analysis technique

SPRUCE Survey

- Example questions:
  - Does your group utilize a formal process model for the definition, planning and management of numerical analysis? If yes, how is it related to the quality management system of your organization?
  - Are you familiar with the following definitions of model Verification and Validation?
- ***Verification***: the process of determining that a model implementation accurately represents the developer's conceptual description of the model and the solution to the model (i.e. determining if you built the model right).
- ***Validation***: the process of determining the degree to which a model is an accurate representation of the real world from the perspective of the intended uses of the model (i.e. determining if you built the right model).

SPRUCE Survey

- Example questions:
  - Estimate the relative contribution of different factors to make a statement about the quality of a numerical analysis:
    - personal responsibility/competence
    - supervision during analysis by qualified/project team
    - peer review by internal or third-party experts
    - outcome of V&V
    - conformity to guidelines or standards (e.g. NAFEMS QSS to ISO 9001)
  - Potential added value from standardization for numerical modelling?

SPRUCE Survey

- Analysis: basic statistics (e.g. mean) and qualitative analysis to identify some patterns in the free text questions
- Limitations of the study:
  - No rigorous design sample
  - ”Empirical” formulation of the questions
- Main consequences: no hypothesis testing, bias, no optimized extraction of information from the qualitative questions

Ongoing and Future Work

- Analysis of collected answers in progress (still in time for a few last minute!)
- Project workshop to discuss current needs and develop a roadmap for concrete actions (~end of March)
- Presentation of the project outcomes at NAFEMS Nordic Conference, 26-27 May 2020, Gothenburg
- State of the art and survey analysis will be publicly available on VINNOVA's website
- Possible future direction: standardization for AI, ML?