[D.4.3] : Stakeholder Feedback Report from Consultation Event

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1 Executive Summary

This report summarises feedback gathered through stakeholder engagement activities undertaken within STOCHASTICA, including discussions at the Directions Workshop, stakeholder applications, and interactions through the SNIP seminar series. Stakeholders represented academia, industry, public research institutes, and government-related organisations with interests spanning stochastic differential equations (SDEs), stochastic partial differential equations (SPDEs), statistics, uncertainty quantification, machine learning, forecasting, and decision-making under uncertainty. The STOCHASTICA Directions Workshop, showcased applications of stochastic modelling in ecology, epidemiology, climate science, energy systems, machine learning, fluid dynamics, signal processing and financial mathematics.

A central finding is that stakeholders across diverse application domains face similar challenges involving prediction, data assimilation, parameter estimation, uncertainty quantification, and the analysis of complex systems under uncertainty. There is strong demand for methodologies that combine rigorous mathematical foundations with practical and computationally accessible tools.

The consultation highlighted enthusiasm for developing a STOCHASTICA toolbox that would facilitate the transfer of stochastic methodologies between disciplines. Stakeholders emphasised the need for benchmark problems, domain-specific case studies, accessible documentation, interactive training materials, and potentially an AI-assisted interface to support navigation and method selection.

2 Stakeholder Landscape

The consultation revealed a broad and diverse stakeholder ecosystem. Across all sectors, uncertainty quantification and robust decision-making emerged as common priorities.

2.1 Academia

Academic stakeholders were drawn from mathematics, statistics, physics, biology, ecology, climate science, engineering, finance and computer science. Interests ranged from theoretical developments in stochastic analysis to applications involving forecasting, optimisation and machine learning.

2.2 Industry

Industrial stakeholders represented sectors including:

- Energy systems and infrastructure
- Financial modelling and risk assessment
- Data science and machine learning
- Engineering and technology development

2.3 Government and Public Research Bodies

Government-linked organisations and public research institutes highlighted needs related to:

- Climate and environmental modelling
- Public health and epidemiology
- National standards and measurement
- Forecasting and decision support

3 Key Themes Emerging from Stakeholder Feedback

3.1 Biology, Ecology and Health

Stakeholders working in biology, ecology and health identified several common challenges:

- Epidemiological and population dynamics models
- Gene and biochemical network models
- Climate and ecological tipping points
- Parameter estimation and model calibration
- Forecasting and data assimilation
- Inference from noisy and incomplete observations

There was substantial interest in methods for stochastic simulation, inverse problems, state estimation and machine-learning-enhanced modelling approaches.

3.2 Geophysics and Environmental Sciences

Researchers and practitioners in geophysics emphasised:

- Weather and ocean forecasting
- Multiscale modelling
- Reduced-order and dimension-reduced models
- Data assimilation
- Uncertainty quantification
- Transport-noise SPDEs

Stakeholders highlighted opportunities to integrate stochastic modelling with modern AI and machine learning approaches while maintaining physical consistency and interpretability.

3.3 Energy Systems

Stakeholder interests included:

- Load forecasting
- Wind energy systems
- Asset degradation modelling

- Thermal system modelling
- Decision-making under uncertainty

A recurring message was the need for practical tools capable of delivering actionable predictions together with reliable uncertainty estimates.

3.4 Computing, Statistics and Machine Learning

Strong interest was expressed in the interface between stochastic mathematics and modern computational approaches:

- Stochastic gradient descent
- Learning from partial observations
- Bayesian inference
- Large-scale time-series analysis
- Data-driven model discovery

Stakeholders sought methods that combine statistical rigour with scalability and computational efficiency.

3.5 Physics and Engineering

Applications identified by stakeholders included:

- Early warning systems
- Signal processing
- Biomedical imaging
- State estimation
- Critical transitions and phase transitions

Particular emphasis was placed on preserving physical structure within computational methodologies.

3.6 Finance and Risk

Feedback from finance stakeholders focused on:

- Forward-backward SDEs
- Risk evaluation
- Pricing and volatility models
- First-passage problems
- Optimal control

Financial applications continue to provide an important source of both methodological challenges and practical use cases.

4 Cross-Cutting Research Priorities

Across application domains several recurring themes emerged.

4.1 Forecasting and Prediction

Stakeholders consistently seek improved forecasting capabilities for complex systems operating under uncertainty.

4.2 Data Assimilation and State Estimation

The integration of observations with mathematical models remains a major challenge in areas ranging from environmental science to engineering and biology.

4.3 Parameter Estimation and Inverse Problems

Extracting information from noisy and incomplete data is viewed as a central challenge across all sectors.

4.4 Uncertainty Quantification

Reliable estimates of uncertainty are increasingly required to support policy decisions, operational planning and scientific understanding.

4.5 Machine Learning and Data-Driven Modelling

There is considerable interest in combining stochastic modelling with modern machine learning methods while retaining interpretability and scientific credibility.

4.6 Tipping Points and Early Warning Signals

Stakeholders identified the detection of critical transitions as an important challenge with applications in climate science, ecology, infrastructure management and engineering.

5 Feedback on a STOCHASTICA Toolbox

Stakeholders were highly supportive of creating a STOCHASTICA toolbox but emphasised the need for accessibility and usability.

5.1 Core Principles

The toolbox should:

- Avoid unnecessary technical jargon.
- Support non-specialist users.
- Provide practical guidance on method selection.
- Include worked examples and demonstrations.
- Facilitate cross-disciplinary knowledge transfer.
- Support both research and training activities.

5.2 Benchmark Problems

One of the strongest recommendations from stakeholders was the creation of benchmark problems.

Each benchmark should contain:

- A clearly defined scientific or operational challenge.
- Representative datasets.
- A foundational model description.
- Suggested performance metrics.
- References and further reading.

Benchmark collections could be organised around themes such as:

- Biology and ecology
- Geophysics and climate
- Energy systems
- Engineering applications
- Finance and risk

5.3 Knowledge Transfer Resources

Stakeholders suggested the development of:

- Targeted review articles
- Application-oriented technical notes
- Interactive tutorials and demonstrations
- Domain-specific case studies

5.4 AI-Assisted Access

An AI-enhanced interface to support use of the toolbox was proposed. Potential capabilities include:

- Natural language search
- Method recommendation systems
- Guided workflows
- Educational support and explanations
- Automatic linking to benchmark examples

6 Future Directions for Stakeholder Interaction

6.1 Establish a Continuing Stakeholder Network

Stakeholders expressed support for maintaining engagement beyond individual events.

Possible mechanisms include:

- Annual stakeholder workshops
- Thematic online seminars
- Community discussion

6.2 Develop Domain-Focused Communities

Targeted engagement groups could be established around:

- Biology and health
- Geophysics and climate
- Energy systems
- Artificial intelligence and data science
- Engineering and physical systems
- Finance and risk

These communities would help identify emerging challenges and opportunities for collaboration.

6.3 Co-Design Research Challenges

Stakeholders should actively contribute to defining future research priorities.

Particular interest was expressed in:

- Data assimilation
- Early warning indicators
- Uncertainty quantification
- Data-driven stochastic modelling
- Forecasting under uncertainty

6.4 Strengthen Knowledge Exchange Activities

Future activities could include:

- Interdisciplinary training schools
- Benchmark problem workshops
- Practitioner-focused tutorials
- Shared datasets and computational resources

6.5 Improve Communication and Visibility

Stakeholders recommended:

- A dedicated public-facing resources webpage
- Plain-language descriptions of research activities
- Impact case studies

7 Future Directions for Toolbox Development

7.1 Short-Term Priorities

1. Solicit benchmark problems from each Working Group.
2. Collect representative datasets and use cases.
3. Develop contribution guidelines.
4. Create standard templates for toolbox entries.

7.2 Medium-Term Priorities

1. Produce introductory and non-technical materials.
2. Organise a dedicated benchmark workshop.
3. Develop exemplar workflows and tutorials.

4. Build domain-specific benchmark collections.
5. Create interactive educational resources.
6. Establish quality-control and review procedures.

7.3 Long-Term Priorities

1. Develop an AI-assisted toolbox interface.
2. Build a sustainable community contribution framework.
3. Link benchmark problems across application areas.
4. Support reproducible computational workflows.
5. Establish the toolbox as a recognised community resource for stochastic modelling and uncertainty quantification.

8 Immediate Actions

Based directly on stakeholder feedback, the following actions are recommended:

1. Solicit two or three benchmark problems from each Working Group.
2. Survey stakeholders regarding available datasets, societal impact, foundational models and training needs.
3. Organise a dedicated workshop to refine benchmark problem definitions and associated documentation.
4. Develop contribution standards to ensure consistency across toolbox resources.

9 Evidence from the Directions Workshop Programme

The stakeholder consultation was supported by presentations from invited speakers representing academia, industry, public-sector organisations and research institutes. The programme was deliberately structured to highlight current challenges and opportunities for the application of stochastic differential equations across a wide range of sectors. The invited talks reinforced several of the themes identified during the consultation and provided concrete examples of emerging research challenges. These included:

- Ecological and agricultural modelling, including opportunities and barriers to the use of stochastic differential equations in applied biological systems.
- Detection and estimation of tipping points and early warning indicators in complex systems.
- Infectious disease modelling and the role of stochastic methods beyond deterministic approaches.
- Stochastic optimisation and stochastic gradient algorithms arising in machine learning.
- The impact of noise and numerical precision in modern AI systems.
- Uncertainty quantification and surrogate modelling using Gaussian processes.
- Forecasting and decision support for energy distribution systems.
- Multiscale and non-Gaussian data assimilation methods for weather and ocean models.
- Noise-driven mechanisms in biological systems.
- Tipping-point analysis in real-world complex systems.
- Deep-learning approaches for forward–backward stochastic differential equations.
- Dynamic risk evaluation using backward stochastic differential equations.
- Bayesian filtering for continuous-discrete stochastic systems.
- Stochastic partial differential equations in fluid dynamics.
- Structure-preserving stochastic models for fluid flows.

The breadth of topics represented confirms that the challenges faced by stakeholders are often shared across disciplines. For example, forecasting, uncertainty quantification, state estimation, parameter inference, machine learning integration, and decision-making under uncertainty appeared repeatedly across talks from biology, climate science, engineering, energy systems and finance.

The workshop provided strong evidence that a common methodological framework based on stochastic modelling has the potential to facilitate knowledge transfer between traditionally separate application domains. This observation further supports the development of a shared STOCHASTICA toolbox built around benchmark problems, reusable methodologies and application-focused guidance.

10 Conclusions

The consultation event demonstrated substantial interest in stronger interactions between stochastic mathematics researchers and stakeholders from academia, industry and government. While application areas differ, common challenges arise repeatedly around uncertainty quantification, forecasting, inference, data assimilation and decision support.

The proposed STOCHASTICA toolbox provides an opportunity to create a shared resource that lowers barriers to adoption, encourages interdisciplinary collaboration and accelerates the transfer of methods between domains. Continued stakeholder engagement through workshops, benchmark activities and collaborative development will be essential to maximise the scientific and societal impact of the initiative.

Sources of Stakeholder Input

This report is based on:

- Stakeholder information gathered during STOCHASTICA Action membership applications.
- Discussions and feedback obtained during the STOCHASTICA Directions Workshop (University College Cork, 27–29 April 2026).
- Contributions from speakers and participants in the STOCHASTICA SNIP seminar series.
- Working-group discussions held during the Directions Workshop.
- The stakeholder mapping exercise undertaken within STOCHASTICA.