Open Call Collection OC-2016-2

Proposal Reference OC-2016-2-21490

Title: Developing and mainstreaming methods and tools for sensitivity analysis of mathematical models

Acronym: DM-SAMO

Summary

The use of mathematical models suffers from the lack of agreed theory and standards of general validity, as modelling is to a large extent discipline-specific. In particular methods for the quality assurance of models appear inadequately developed and could benefit from more communication and exchange of practices among disciplines. Sensitivity analysis is considered by practitioners a useful and desirable practice to solve a sizeable fraction of the issues associated to the quality assurance and plausibility of models. Existing sensitivity analyses seen in the literature are of an extremely poor quality, due to the lack of agreed disciplinary standards and structured teaching on the subject. The fragmentation of the existing community of sensitivity analysis practitioners results in a tremendous waste of research resources. The use of inadequate method also leads to waste in industrial and commercial applications of mathematical models. Last but not least the present parallel crisis is science reproducibility and science advice functions also affect the use of statistical and mathematical models. This COST action will make sensitivity analysis into a recognized discipline and bring state of the art solutions to all functions and fields of application of modelling. This will be achieved by coupling the identification of good practices with their mainstreaming to the appropriate disciplinary and educational. A repertoire of exemplary industrial application will also be populated via cooperation with private and public partners. The knowledge acquired with the Action will finally be distilled into a Massive Open Online Course (MOOC) on sensitivity analysis for reliable quantification.

Key Expertise needed for evaluation

Computer and Information Sciences
Mathematics applied to computer science, mathematical aspects of computer science
Other engineering and technologies
Applied mathematics, statistics, non-computational modeling for other engineering and technology
Other social sciences
Quantitative methods for the social sciences
Other social sciences
Databases, data mining, data curation, computational modelling

Keywords

Sensitivity analysis

Uncertainty analysis

Mathematical modelling

Computer simulation

Model validation, verification and quality assurance

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1. S&T EXCELLENCE

1.1. Challenge

1.1.1. Description of the Challenge (Main Aim)

According to Robert Rosen, one of the fathers of modern ecological economics, modelling is not a science but rather a craft. Rosen motivates this position with the impossibility to entail ‘model’ and ‘system modelled’ within an unambiguous causal framework. In other words, given the same system, multiple representations of the system are possible, even in the context of a closed set of specifications. This is perhaps one of the reasons why mathematical modelling is not a discipline per se and every branch of science goes about modelling following its own cultures and practices.

As a result, an incalculable waste of resources takes place because modellers worldwide cannot give themselves a unified, reliable and agreed-on code of good practices for testing their models and the quality of the inference they produce. Unsurprisingly, the quality of model based inference has often been found wanting and – what is worse – problematic to assess.

This becomes an unacceptable burden given the central role of modelling to all aspects of the scientific enterprise as well as to its commercial, industrial and societal functions. A study using numerical models is necessarily tainted by errors of diverse nature, linked to the model coding and formulation, the input data, the discretization choices, the numerical resolution steps and so on, up to and including the framing and biases involving the engineer himself. For the sake of relevance, credibility and productivity, it is important to have a firm grasp of the level of error committed in relation of the task being pursued, without assuming uncertainties away.

Sensitivity analysis is a cross-cutting statistical discipline that examines the sensitivity of mathematical models to changes in their assumptions. It is capable of meeting a broad set of functions related to the quality of a model – including model validation and calibration - but the discipline is underdeveloped. Although the overall amount of resources involved in sensitivity analysis research is not inadequate, its practitioners are scattered over several countries, and pockets of activity can be found in various disciplines across science and engineering, which are themselves poorly connected. Moreover, preciously few researchers are engaged in teaching the subject. This arrangement cries for a better coordination, the impact of which would be formidable given the omnipresence of statistical and mathematical models at the heart of science (both natural and social) and technology.

Since the industrial applications of sensitivity analysis are almost limitless, there is a huge loss of potential efficiency in modelling which results from a poor grasp of sensitivity analysis. All disciplines use mathematical or statistical modelling of one form or another, so the economic and societal benefits which could be achieved by a well-established theory are very substantial.

Additionally, mathematical and statistical models – besides being at the core of practically every industrial process or product - are also at the core of important science-advice functions, e.g. in evidence-based or evidence-informed policy.

The main thrust of the Action titled ‘Dissemination and Mainstreaming of Sensitivity Analysis of Model Output’ (acronym: DM-SAMO) is thus to increase the quality of model-based practice by consolidating and mainstreaming sensitivity analysis into a recognized discipline, to provide a forum for jointly identifying good practices, to test relevant and exemplary applications to industrial and other social domains, and to disseminate it across countries, cultures and disciplines. A Massive Open Online Course (MOOC) will condense all lessons learnt in the course of the Action into a format apt for wide dissemination.

1.1.2. Relevance and timeliness

At the time of writing this proposal, there are serious alarms about the quality control mechanism of science. This is also known as the reproducibility crisis, but in fact it affects peer review, the use of metrics, and the system of rewards in use in the scientific community. Models and statistical tools used for inference are especially the subject of a concerned reflection. Examples from various contexts include the use and misuse of statistics, such as in the case of the p-test (Wasserstein and Lazar, 2016); the use of theoretical models as instruments for prediction and policy assessment (notably in economics) and the resulting model failures; and misdiagnoses in several policy fields, from nutrition to forensics, and from psychology to medicine. Estimates of the cost of these failures are not available for the specific case of models, but those for science overall are staggering if – as is the case for medicine – more than half of the results produced are not actually reproducible (Ioannidis, 2016).

Most practitioners are aware that a well-conducted sensitivity analysis can easily anticipate problems – e.g. by identifying cases where predictions are irrelevant because of the existing uncertainty, or by identifying regions for subsequent calibration and optimization, for the solution of inverse problems and so on via a myriad of potential applications.

At the same time sensitivity analysis is used sparingly; it is rarely taught in university courses, and when performed it is mostly of an unsatisfactory quality. Most sensitivity analysis seen in the academic literature are totally inadequate to map the true uncertainty in model inference (Ferretti et al., 2016). The exceptions are the papers written by SA practitioners, with the unfortunate result that SA-related papers fall into two classes: proposals for new or refined methods – with illustrative applications – written by SA practitioners, or application papers with relevant scientific content and often poor-quality sensitivity analyses. Even the journals where these works appear are mostly different for the two classes.

The family of sensitivity analysis practitioners is spread over many disciplines and countries and there are dramatic differences in the SA-capacity and maturity of different contexts. The only official existing link among practitioners is a conference (SAMO) held once every three years since 1995, the eighth instalment of which was in November 30th - December 3rd, 2016 at Le Tampon, La Reunion (France); see http://samo2016.univ-reunion.fr/. A previous related initiative called MUCM “Managing Uncertainty in Complex Models”, which included sensitivity analysis in its remit and was active mostly in the UK, is no longer active.

And yet wherever sensitivity analysis is used it manages to establish itself as a precious tool and philosophy. In France a Research Group named MASCOT offers training on numerical experiments at Master level students, see http://www.gdr-mascotnum.fr/professional_training.html. In the UK, sensitivity analysis is among the remit of a special interest group named Uncertainty Quantification and Management in High Value Manufacturing (see https://connect.innovateuk.org/web/uncertainty-quantification-and-management-in-high-value-manufacturing/overview). The COST program was exposed to sensitivity analysis in the COST Action TU0903 – MULTITUDE, which introduced SA in the transportation engineering field. Additionally, there have been two COST actions with a focus on uncertainty: one in meteo-hydrological forecasting (731), and one on an expert judgement network (IS1304). There have been no COST actions specifically on sensitivity analysis.

In the US, SA-related activities go under the heading of ‘Verification, Validation and Uncertainty

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Quantification' (VVUQ), for which a journal of the American Society of Mechanical Engineers is available (http://verification.asmedigitalcollection.asme.org/journal.aspx). China is also a geographic area which has seen a true explosion of research work on sensitivity analysis in recent years.

The disciplinary nature of the organization of research is partly responsible for the existing sluggishness to accept SA. For one, its use forces modellers to adopt stricter standards of modelling practice; for another it may show that model predictions do not resist a test of robustness. The main issue is nevertheless that SA is not a recognized discipline, and the proposed DM-SAMO Action would aim to tackle this problem head on as the first truly international and cross-disciplinary initiative of its kind. Coordination is the only way to achieve such a breakthrough and the timing of the present proposal is appears ideal.

1.2. Objectives

1.2.1. Research Coordination Objectives

The DM-SAMO Action has two broad aims in terms of coordination. The first is to improve links between poorly-connected pockets of researchers and advanced practitioners of sensitivity analysis, in order to accelerate progress and minimise duplication of research. The second is to better connect the sensitivity analysis research community with the wider modelling communities across science, engineering and elsewhere. In order to achieve these objectives, the following points of action are envisaged:

- To develop and mainstream approaches to global quantitative sensitivity analysis of model output (i.e. full, rather than partial exploration of the space of assumptions) which can be applied to a broad class of problem settings, model characteristics, and output configurations such as scalars, maps or time series.

- To investigate the discipline specific needs of the different modelling communities, their cognitive and cultural attitudes and biases, and the room for common solutions.

- The above implies to formulate and to agree to the extent where this is possible on:

  - A terminology and a taxonomy;
  - A list of open key questions to be addresses by dedicated workshops;
  - A set of good practices mapped to the identified problem areas;
  - Elements of epistemology specific to use of statistical and mathematical models. (Epistemology is a branch of philosophy which studies how do we decide what do we know, how is knowledge to be pursued)

- To make this discipline available through the preparation of adequate syllabuses.

- To advocate to the effect that these syllabuses be taken up by educational institutions at graduate and post-graduate level in the broadest set of disciplines. To this effect a partnership could be established to develop a MOOC (Massive Open Online Course) on sensitivity analysis and reliable quantification.

- To provide summer schools in as many countries as possible including target countries.

- To run a series of round robin methods intercomparisons

- To run dedicated workshops related to the round robin exercises above.

- To provide supporting material – both conceptual and practical – so that the above can be achieved, including easy to use software in the most widespread computer languages.

- To intensify contacts among practitioners, e.g. making the SAMO conference into a yearly event during the period covered by COST.

- To better publicise (via website and network tools) and promote sessions in sensitivity analysis at international conferences in diverse fields.

The above objectives are measureable with indicators such as

- Number of review papers on disciplinary journals related to the solution offered to known challenges
- Number of higher education institutions taking up the syllabus
- Number of students taking the MOOC
- Number of training events
- Number of round robin intercomparisons studies
- Number of SAMO conferences held during the Action

1.2.2. Capacity-building Objectives

The main objective of DM-SAMO is to develop, implement and promote the use of methods and procedures for sensitivity analysis in the context of mathematical and statistical modelling and their applications as to increase the effectiveness and reliability of model use.

The objectives are as follows:

State of the art in sensitivity analysis across disciplines

- To perform a literature survey on major disciplinary journal to identify specific characteristics, cultures and needs, as well as classes of problems most commonly met.

A map of the most relevant areas of development and open issues needing either development and/or mainstreaming. Areas of likely intervention include

- revised taxonomy for settings in sensitivity analysis,
- tailoring of different global quantitative measures and methods to different settings ,
- sensitivity analysis formulation with system models (e.g. 0D-1D models) and coupled models,
- sensitivity analysis applied to optimization problems,
- sensitivity analysis related to the uncertainty of the input probability distributions,
- design, sampling and random numbers generation
- use of efficient methods for time consuming simulations,
- graphical tools to analyse sensitivity effects in high dimension,
- treatment of geographically distributed outputs or time series,
- treatment of multiple outputs
- treatment of correlated inputs
- models defined in non-rectangular domains (constraints between inputs),
- metamodels and their application to sensitivity analysis
- inventory and comparison of available software for sensitivity analysis
- …

Synthesis, dissemination and training

- Deployment of appropriate documentation of teaching resources, such as case studies, handbooks, and videos.
- Preparation of common and discipline specific guidelines as well as input to existing guidelines
- Syllabuses to be tested in selected educational institutions
- Training in partners and candidate countries for both for early stage-researchers and practitioners
- Yearly international conference
- Review papers on disciplinary journals
- Creation of web based resources
- Maintenance and monitoring of online sources (e.g. Wikipedia)
- …

Round robin exercises of method intercomparisons

- On metamodeling
- On speed and accuracy of computation
- On efficient sampling design
- …

1.3. Progress beyond the state-of-the-art and Innovation Potential

1.3.1. Description of the state-of-the-art

Recent reviews of sensitivity analysis are Norton (2015), and Wei et al. (2015). Special issues have been devoted to sensitivity analysis in Reliability Engineering and System Safety (2006, 2012, 2015), and the Journal of Statistical Computation and Simulation (2015). Several textbooks for sensitivity analysis are also available which are reviewed in e.g. Norton (2015).

Sensitivity analysis is acknowledged as a useful practice in model development and application. Its use in regulatory setting – e.g. in impact assessment studies – is prescribed in guidelines both in Europe and the United States (European Commission, 2015, p. 390-393; Office for the Management and Budget, 2006, p. 17-18; Environmental Protection Agency, 2009, p.26).

There are several software for sensitivity analysis; one called SIMLAB is developed by the JRC (see https://ec.europa.eu/jrc/en/samo/simlab); others are mostly 'R' (especially in France, see later in this proposal) or Matlab and FORTRAN implementations by SA practitioners in the open source domain. No application has gained universal traction so far, again for a lack of a disciplinary focus. A recent (2016) review of software for uncertainty quantification which included SA tools was prepared by the project QUICS (Quantifying Uncertainty in Integrated Catchment Studies, funded by the EC' s 7th framework programme, see https://www.sheffield.ac.uk/polopoly_fs/1.586704!/file/QUICS_Deliverable_2.1_v4Final.pdf)

To the knowledge of the proponents no national initiatives has been taken focused specifically on sensitivity analysis.

There are instead several sectorial actions in the field of modelling with where SA is or could be beneficial – for example there was a COST Action (TU0903) on traffic simulation models which usefully adopted sensitivity analysis.

As described in section 1.1.2 above sensitivity analysis is as much practiced as it should be and – when used – it is not of a satisfactory quality (Ferretti et al., 2016). Further it is not part of the teaching programs in institutes of higher education. Even talented practitioners are unable – for lack of a critical mass – to bring these shortcomings to the attention of a wider scientific public. To make an example the only sensitivity analysis paper ever published in a high rank generalist scientific journal was a paper in SCIENCE in 1989, by Herschel Rabitz. At present SA practitioners resort to the 'Projects' feature of Research Gate for cooperative work. A better home for these activities is needed.

1.3.2. Progress beyond the state-of-the-art

There are quite a number of unresolved issues in the emergent discipline of SA whose resolution requires joint analysis, testing, intercomparisons and joint deliberation among practitioners.

To make an example the meaning of the term 'importance' in relation to a factor, when it is said that factor A is more important than factor B, needs a careful specification. One has to define beforehand importance – in relation to the application at hand – lest many different measures of importance can be thrown at the problem as to get different ordering of the relative importance of input factors. In the literature often this correspondence between task and measures of importance appears wanting.

Related questions are what SA method is better suited to what application or setting, what sampling scheme should be considered as best practice in factors screening (a form of SA at low sample size) and SA proper, what metamodeling strategy is the most effective and so on (see section 1.2.2 above). These issues emerge every time the practitioners meet (e.g. in the SAMO context every three years) but this rarefied occurrence limits the speed of convergence and resolution of the open questions. The present COST Action aims to tackle these problematic areas already in the first two years of activity so that a proper activity of mainstreaming can be put in place within the scope of the Action.

Important specific questions also arise in the application of sensitivity analysis, concerning how it can be rigorously applied to large models in climate science, industry and economics.

1.3.3. Innovation in tackling the challenge

As discussed above most research on sensitivity analysis is run by a relatively small group of practitioners, while most modellers adopt ad hoc solutions to their modelling needs which are often dramatically insufficient. To make an example the most widespread approach seen in the literature is that of moving One factor At a Time (OAT methods), which results in leaving most of the space spanned by the input factors unexplored. All practitioners know that this approach should be discouraged but whom to talk to? The disciplinary nature of the modelling craft – and the absence of SA from study curricula – makes this cross fertilization arduous.

For this reason a coordination effort is needed focusing on the choice of methods corresponding to different technological, industrial and social settings. Formulating agreed specifications for model calibration and verification, situating sensitivity analysis in the context of model use and creating an epistemology relevant to knowledge produced by mathematical and statistical models will give European research a unique advantage in disciplines from chemistry to psychology, and from engineering to economics. The most important innovation of DM-SAMO is the multi-disciplinary coordination of efforts as the necessary catalyst for the achievement of the objectives. COST the ideal instrument to achieve this. The combination of industrial experience with academic insight allowed by the Action and the resulting MOOC are also elements of innovation.

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1.4. Added value of networking

1.4.1. In relation to the Challenge

From the EU perspective, coordination of such topics is overdue. The European Commission has spearheaded the use of sensitivity analysis methodologies both with its guidelines for impact assessment (2015) and the relevance given to sensitivity analysis by the EC own Joint Research Centre (see https://ec.europa.eu/jrc/en/samo). To the knowledge of the proponents no indirect action has been funded so far focused on sensitivity analysis, though SA was used intensively e.g. in the EC funded nuclear safety studies (projects PAGIS in the eighties and PAMINA, ended in 2009). An intercomparisons of sensitivity analysis methods (called PSAG – Level S) was run by the Organization for the Economic Cooperation and Development – Nuclear Energy Agency (OECD-NEA) in 1993.

At present (data till 2014, Ferretti et al., 2016) both the European Union and the US represent roughly 40% each of the total production of articles in global sensitivity analysis with Canada and China splitting the remaining 20%. China is nevertheless the region with the highest rate of growth. The present trend shows that lacking a rapid European effort China might become the main player in the field, which would advantage this region in the present manufacturing competition against EU players. On EU network to leverage existing European resources is hence necessary and timely.

1.4.2. In relation to existing efforts at European and/or international level

The horizontal nature of the proposal makes it complementary to the H2020 program overall, to the extent that modelling is ubiquitous and sensitivity analysis a recognised necessity. Moreover, an essential challenge has recently appeared in many applicative issues involving simulated systems: the verification and validation (VV) steps. Verification deals with the correct solving of the model equations by the computer, while validation concerns the comparisons between model predictions and real observations in order to give some credibility to the computer simulations. Combined with the uncertainty quantification (UQ) step, the so-called VVUQ process recognises sensitivity analysis as a necessity. As mentioned in section 1.1.2 there appear to be no specific effort on sensitivity analysis in the EU and national programs at present.

2. IMPACT

2.1. Expected Impact

2.1.1. Short-term and long-term scientific, technological, and/or socioeconomic impacts

In the short term DM-SAMO would put the initiative back into the European Union, and consolidate sensitivity analysis as a discipline. Moreover, sensitivity analysis development will support:

- the strong engineering skills which are needed at the present time to answer to new safety requirements in risky industries, e.g. in aerospace development and energy production,
- the increasing industrial need to manage uncertainties either at the early phases of the design or during qualification/certification phases of a product or a service,

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- the simulation-optimization based processes which allows considerable margins of improvement.

In all these issues, our main goal is to provide confidence indexes and/or sensitivity indexes that can better inform decision-making. In the longer term, this would allow the penetration of the discipline into study curricula, the training of young researchers and the upgrade of the modelling skill of the EU players in both industry and academia. Industrial applications e.g. in simulation and optimization research will be considerable. The MOOC will ensure a long lasting impact of the Action.

2.2. Measures to Maximise Impact

2.2.1. Plan for involving the most relevant stakeholders

The audience of the DM-SAMO Action is in vast and some structuring is needed, especially as far as disciplinary and industrial applications are concerned. For this reason the Action will apply a strategy of identifying 'exemplary' users and applications on which to focus both the tailoring and the dissemination activities.

A convenient partition of the stakeholders is hence:

- The community of practitioners itself
- Higher education institutions
- Selected (exemplary) users in academic disciplines in natural and social sciences.
- Selected (exemplary) industrial partners. While historically the nuclear safety sector has been the cradle of sensitivity analysis methods in industry other important sectors (automotive, chemical, engineering in general) need to be better populated with SA ides and approaches.
- The policy makers involved in impact assessment and scientific advice. In the European Commission the Secretariat General. In the European Parliament the STOA group and the Impact Assessment Directorate. Also relevant could be the INGSA group (International Network for Government Science Advice), collecting also member states and regional authorities. Regulatory bodies would also be a primary target.

The Action will target each audience adopting the most appropriate dissemination methods according to the following table:

Stakeholder	Dissemination Approach
The community of sensitivity analysis practitioners	Networking within the present Action; workshops and SAMO events; round robin tests.
Higher education institutions	Syllabuses; didactic material including software; workshop and SAMO conferences; training events; partnership for a MOOC
Exemplary users – Academy	Disciplinary articles; exemplary applications; training events; software
Exemplary users – industry	Guidelines; exemplary applications; training events; consultancies; software
European and national level policy makers	Guidelines and input to existing guidelines; case studies and final reports, workshops and conferences

2.2.2. Dissemination and/or Exploitation Plan

In order to ensure effective dissemination, specific tasks will be assigned within the WG4 (see section 3.1.1 below), such as planning didactic materials, drawing up guidelines and organizing the training school and SAMO events. The same procedure will be applied in coordination with WG1, WG2 and WG3 for the targeted actions to involve disciplinary and industrial partners and policy stakeholders.

The Core Group (see section 3.1.1 below) will regularly review the plan of dissemination according to results of its evaluation.

The kick off meeting will be instrumental in identifying those dissemination tasks which can be immediately set into motion, pending the input from the WG1, WG2 and WG3.

Among these

- A training school for early stage-researchers and practitioners will take place within the first 100 days of the project.
- The design of an outreach strategy to inform stakeholders in the industrial, academic and policy domain of the existence of the Action

The selection of an academic partner for the realization of a MOOC will also be among the most urgent initiatives.

The rest of the plan is detailed below in section 3.1.1 in relation to the activities of the Working Group 4.

2.3. Potential for Innovation versus Risk Level

2.3.1. Potential for scientific, technological and/or socioeconomic innovation breakthrough

The most spectacular scientific advances – from the detection of gravitational waves and the Higgs boson to the posing of a probe on a comet flying past the sun, require the smooth operation of a myriad of mathematical models and associated software. So much so that the most known failures in this class of achievements is due to faulty software design. A known secret of sensitivity analysis is that it is never run without this leading to the identification of more bugs (an instance jokingly known among computer nerds as ‘Lubarsky's Law of Cybernetic Entomology’). The kind of breakthrough made possible by a diligently run sensitivity analysis are of the kind not reported in the media, simply because the rocket’s engines worked as planned, the flying assistant model gave the right message to the pilot, or the accident or the error simply did not happen. An equivalent situation holds when models are used for policy simulation or assessment. An expenditure program based on a cost benefit analysis which left most of the assumptions untested may easily cost the taxpayers decimals of GDP points with no useful results and missed opportunity costs.

Uncertainty also has many dimensions. Richard Feynman discovered while investigating the Challenger disaster that, while the low temperature and the properties of the O-Rings could explain the material cause of the accident, its final causes were institutional and were found in the socio-political organization of NASA (https://www.youtube.com/watch?v=4kpDg7MjHps) and the drive of its management to go beyond what the engineers recommended. By coupling more conventional sensitivity analysis (concerned e.g. with the O-Rings type of uncertainties) with an extended sensitivity analysis (concerned e.g. with the motivation and stakes of the actors), this Action moves the frontier of analysis forward, and avoid the shortcoming of model simulations that address technical uncertainty while neglecting other relevant dimensions.

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The relative low cost associated to sensitivity analysis research and the importance of the potential benefits are evident. The avoidance of only one of the accidents just mentioned would give benefits order of magnitude above any cost incurred by both this Action and its underlying research. The increased product performance made possible by SA may decide of the fate of a product in a context of international competition.

3. IMPLEMENTATION

3.1. Description of the Work Plan

3.1.1. Description of Working Groups

The Action foresees four working groups: (i) methodology, (ii) industrial and disciplinary applications, (iii) policy settings and (iv) synthesis and dissemination. The repartition of tasks among the four working groups can be summarized as follows:

(1) Methodology – review and state of the art – measures and methods. This task is articulated as follows:

- Task 1.1 Mapping of the state of the art and of the major gaps in understanding, or area of contention. Agreement on settings and mapping of the methods to the settings. Suggesting an agenda for research and round robin tests.

- Task 1.2. Troubleshooting the open hot issues. This is the major link of the Action to the research coalface, on topics which are likely to include (i) design, sampling and random numbers generation (ii) Acceleration of computation (iii) Treatment of geographically distributed outputs or time series, (iv) Treatment of multiple outputs, (v) Treatment of correlated inputs and of models defined in non-rectangular domains.

- Task 1.3 Metamodels. These are methods which represent the response of the model using computationally inexpensive functions (generalized linear models, polynomials including polynomial chaos models, splines, Gaussian processes). These meta- or surrogate models or response surfaces are used for many applications and their importance in the context of sensitivity analysis merits them a separate task. Work in this task will streamline the use of metamodels by type of application and provide guidelines for software selection and use.

- Task 1.4 Epistemology for model use. Although a considerable body of literature exists on what a model represents and how models can be used in the context of a scientific method this kind of knowledge is rather sparingly mobilized. The task will share this knowledge as to promote a more reflexive approach to modelling, one which makes sensitivity analysis central to the modelling process.

- Task 1.5 Round robin exercises of method intercomparisons on metamodeling, computational efficiency, sampling and other following the results of Task 1.1.

(2) Exemplary applications to industry and to disciplinary fields. This is articulated as follows:

- Task 2.1 Selection of an agreed number of relevant (exemplary) case studies. This must include examples of calibration, optimization, and model simplification in important industrial and disciplinary setting.

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- Task 2.2 Preparation of the test cases
- Task 2.3 Submission of the result to relevant fora in cooperation with the dissemination tasks.

(3) Policy applications. This is articulated in the following tasks:

- Task 3.1 This task will focus on providing pragmatic solutions to questions such a “What constitute as evidence in the policy discourse?” “To what extent may model based inference help”? “What can sensitivity analysis contribute to the quality of the evidence?” The results of these reflections may feed into the appropriate fora in the blogosphere, in academia and in science advice’s working groups.
- Task 3.2 Sensitivity auditing. This is a novel extension of sensitivity analysis to policy contexts. Applications and extensions of this approach will be worked out as to provide input to the dissemination activity.
- Task 3.3 Training for policy actors

(4) Synthesis, dissemination and training. This is articulated in the following tasks:

- Task 4.1 Harmonizing approaches and outputs. Based on the results of the tasks in section 1.1 to 1.5 the methodological steps of a sensitivity analysis will be reassessed and reviewed in a general perspective as to provide guidance for the following tasks.
- Task 4.2 Teaching resources. This task concern the preparation of a syllabus for higher education in sensitivity analysis complete of handbook, online material, software identification, web based resources and videos. This task is also responsible for contributing to existing guidelines and developing ad hoc guidelines when this is considered necessary. The end product of this Task is the MOOC.
- Task 4.3 Training. This tasks will organize training in partners and candidate countries for both for early stage-researchers and mature researchers.
- Task 4.4 Networking and reach out activities. This task is responsible for streamlining and spearheading the contact with the stakeholders and for the yearly conference.

The preliminary repartition of deliverable among the different tasks is summarized below. Note that where ‘multiple’ deliverables are indicated the precise list of items will be decided in the initial phase of the Action.

(1) Working Group 1 - Methodology – review and state of the art – measures and methods.

- Deliverable 1.1 State of the art report
- Deliverable 1.2 Agreed agenda for round robin tests
- Deliverable 1.3 Agreed research agenda of open topical issues including meta-models and applied elements of epistemology
- Deliverable 1.4 (multiple) Research and review papers submitted
- Deliverable 1.5 (multiple) Reports and papers from the round robin intercomparisons

(2) Working group 2 - Exemplary applications to industry and to disciplinary fields.

- Deliverable 2.1 Agreed agenda for exemplary applications
- Deliverable 2.2 (multiple) Delivery of application reports for dissemination

(3) Working Group 3 - Policy applications.

- Deliverable 3.1 Report on the Action's prescriptions on the role of sensitivity analysis and modelling in the policy discourse.
- Deliverable 3.2 Report on the outlook for sensitivity auditing applications.
- Deliverable 3.3 (multiple) Delivering of training for policy actors

(4) Synthesis, dissemination and training. This is articulated in the following tasks:

- Deliverable 4.1 Agreed dissemination plan and agenda.
- Deliverable 4.2 Syllabus for higher education in sensitivity analysis
- Deliverable 4.3 Sensitivity analysis handbook
- Deliverable 4.4 Action's web site and other online contacts, such as Facebook and Twitter accounts
- Deliverable 4.5 Report on recommended software
- Deliverable 4.6 (multiple) Videos.
- Deliverable 4.7 (multiple) Training events for early stage-researchers and mature researchers.
- Deliverable 4.8 MOOC (Massive Open Online Course)

3.1.2. GANTT Diagram

See last page

List of Milestones	
Milestone Number	Milestone (**Preliminary**)
1	Completion of Task 1.1 and 2.1 State of the art & identification exemplary cases – Workshop
2	Preliminary results from Tasks 1.4 Epistemology 2.2 Test cases preparation and 4.1 Harmonization – Workshop
3	Final results from Task 1.3 Metamodeling, 1.5 Round robins test and 3.1 Evidence appraisal and sensitivity analysis and 4.2 Teaching resources - Workshop
4	Completion of the project with tasks 2.3 Dissemination of exemplary applications, 3.2 Sensitivity auditing and 4.4 Networking. Release of the MOOC.

3.1.3. PERT Chart (optional)

[Missing]

3.1.4. Risk and Contingency Plans

The main source of risk is associated with the choices which need to be made rather simultaneously at the very beginning of the project. For this reason the rapid formation of the Management Committee, the appointment of the Work Group leaders and Co-leaders and a dynamic start of the activities of the Core group will be essential to the success of the enterprise.

3.2. Management structures and procedures

3.2.1 Coordination and organization
Following the "Rules and Procedures for implementing COST Actions" the Management Committee (MC) will consist of up to 2 representatives from each participating COST country, and will include early-stage researchers.

Four Working Groups (WGs) will be formed, each with a Leader and a Co-Leader appointed by the MC among its members.

The Chair, and Vice-Chair of the Action and the eight Leader and Co-Leader of the four WGs will constitute a Core Group inside the MC, with steering functions. In particular, the Core Group will advise the MC on choosing the research topics and the direction of works, on drawing up detailed plans and arrangements for the distribution of tasks and on defining methods for the different phases of execution of the Action. The Core Group will be in charge of coordinating the contributions from the WGs.

As a general rule the Action will meet twice a year. Again as a general rule the meetings will last for two and a half days. This will include a one-day plenary meeting, a half-day possibly parallel WG meetings, a half-day Core Group meeting and a half-day MC meeting. The possibility of holding such meetings back to back with SAMO event will also be considered to minimize expenses.

The WGs may have additional meetings when deemed necessary by the Management Committee.

Dedicated workshop will be planned on the themes identified in Task 1.1. Outside experts will be invited to give advice and enlarge the application basis of the Action.

Coordination of research will be mainly achieved with a bottom-up approach by sharing and exchanging the experiments run in Tasks 1.2 and 1.3, as well as a result of the method intercomparisons exercises of Task 1.5.

The first milestone of the project will be the preliminary conclusions of Task 1.1, state of the art and open issues.

A second milestone corresponds to the identification of the exemplary applications in industry and academia, analyses of the test cases and harmonization (Tasks 1.4, 2.2, and 4.1). Open workshops will take place at milestones 1 and 2.

A third milestone corresponds to the completion of the round robin tests, the conclusions from application of sensitivity analysis in evidence appraisal and an assessment of the teaching resources collected (Tasks 1.5, 3.1 and 4.2)

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At the completion of the project a balance will be drawn from the Action, including the dissemination of the exemplary cases, sensitivity auditing, training and networking, (Tasks 2.3, 3.2, 4.3 and 4.4)

Books collecting works presented at the workshops will be published in international book series, in order to reach an even wider audience and to expose the results of the Action to international review. The Action may decide to publish all books as Amazon book. These are inexpensive volumes which do not bear the AMAZON logo and whose ISBN number is provided directly by the editors.

3.2.2 Working groups

Four Working groups (WG) are planned for this Action. Each WG is coordinated by a Leader and a Co-Leader, and includes all the participants of the Action who have shown clear interest and motivation to contribute with a defined expertise to the Working Group activities. All Working Groups will meet together during the two annual meetings, with possible joint meetings to be agreed among group leaders.

3.2.3 Gender balance and involvement of early-stage researchers

This COST Action will respect an appropriate gender balance in all its activities and the Management Committee will place this as a standard item on all its MC agendas. The Action will also be committed to considerably involve early-stage researchers. This item will also be placed as a standard item on all MC agendas.

Short-Term Scientific Mission will be activated as much as possible for the early-stage researchers involved in the Action.

The training schools will be devoted to early stage-researchers and practitioners with a particular concern to the gender balance.

3.3. Network as a whole

The network will represent an ideal blend of ages, sexes, and experiences. While some participants are practitioners, others are young researchers. While some deals more with techniques of simulation and metamodeling other are more on estimation procedures, and sampling. Some work mostly on mathematical test functions, others with classic SA applications (e.g. to risk analysis), other on innovative applications of sensitivity analysis for model heuristics.

Some proponents come from countries with a strong presence if sensitivity analysis research others from countries with need to bridge the gap. The mix academy / industry /policy is also ensured. Natural as well as social sciences are represented.

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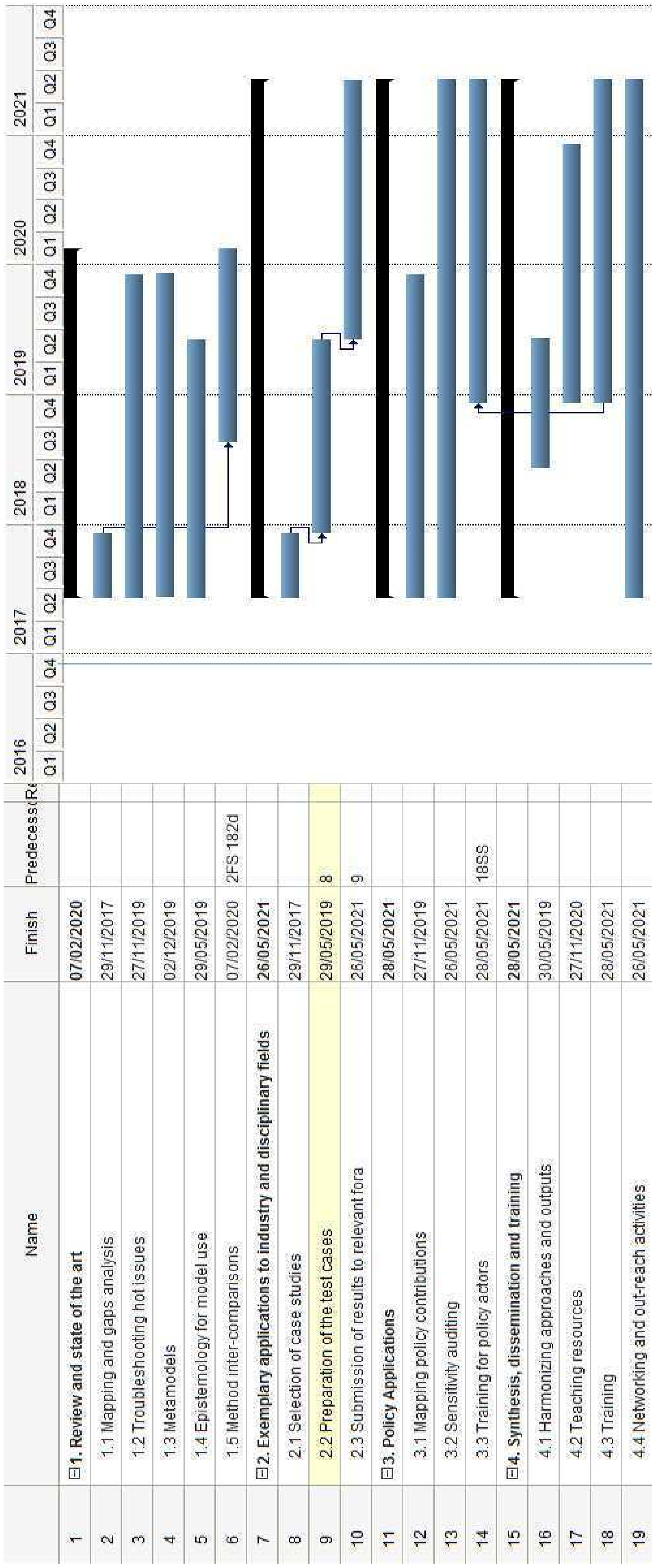

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COST Mission and Policies

The Action DM-SAMO will multiply the impact of existing research in sensitivity analysis onto societal, industrial, political and regulatory domains. It will bridge the gap between different countries, disciplines and applications settings in terms of good practices. This will enhance the usefulness of using mathematical or statistical models in all these domains. DM-SAMO will provide rich opportunities for networking of Early Career Investigators (ECI) thanks to its provision for Training, round robin inter-comparisons projects, and the collective endeavour to mainstream the discipline into academia. The preparation of a MOOC (Massive Open Online course) will feature young researchers. The country balance in the project with 12 COST countries, 1 Near Neighborhood Country (Russia), 3 International Partner Countries (US, Australia and China) and one European Commission/Agency partner satisfies the COST objectives in terms of International Cooperation. Gender balance at 4/6 ratio for women to men is also well respected in this project.

The excellence of the proposal is sustained by the quality of the proponents in terms of their specific competence on the subject domain, demonstrated by their books, their articles and their commitment to the dissemination of the discipline.

The industrial dimension is extremely relevant for this project as modelling underpins any industrial practice, for manufacturing to marketing, from design to logistics and many others.

The policy dimensions is also very relevant as sensitivity analysis is important for policy design (ex-ante impact assessment is largely based on models), policy monitoring and policy evaluation. Regulatory bodies also need sensitivity analysis for their analytic work. This is a fortiori the case for safety authorities.

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Network of Proposers - Features

COST Inclusiveness target countries
33.33 %

Number of Proposers
34

Geographic Distribution of Proposers

Country	ITC/ non ITC/ other	Number of institutions from that country	Number of researchers from that country	Percentage of the proposing network
Australia	other	1	1	2.94 %
Bulgaria	ITC	3	3	8.82 %
China	other	1	1	2.94 %
Czech Republic	ITC	2	2	5.88 %
Denmark	non ITC	1	1	2.94 %
France	non ITC	5	5	14.71 %
Germany	non ITC	2	2	5.88 %
Hungary	ITC	1	1	2.94 %
Italy	non ITC	3	3	8.82 %
Norway	non ITC	2	2	5.88 %
Poland	ITC	2	3	8.82 %
Russian Federation	other	1	1	2.94 %
Spain	non ITC	1	1	2.94 %
Switzerland	non ITC	1	2	5.88 %
United Kingdom	non ITC	4	4	11.76 %
United States	other	2	2	5.88 %

Gender Distribution of Proposers
58.8% Males
41.2% Females

Average Number of years elapsed since PhD graduation of Proposers with a doctoral degree
16.4

Number of Early Career Investigators
16

Core Expertise of Proposers: Distribution by Sub-Field of Science
35.3% Mathematics
14.7% Computer and Information Sciences
8.8% Other engineering and technologies

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5.9% Civil engineering
5.9% Earth and related Environmental sciences
17.4% Other
11.8% Unspecified

Institutional distribution of Network of Proposers

76.5% Higher Education & Associated Organisations
14.7% Government/Intergovernmental Organisations except Higher Education
5.9% Business enterprise
2.9% Private Non-Profit without market revenues, NGO

Private Non-Profit without market revenues, NGO:1

- Number by Type
  Advocacy/Membership Organization:1
- Number by Level
  National:1

Higher Education & Associated Organisations:26

- Number by Field of Science of Department/Faculty of Affiliation
  Chemical engineering:1
  Civil engineering:3
  Computer and Information Sciences:3
  Mathematics:5
  Earth and related Environmental sciences:2
  Other engineering and technologies:2
  Chemical sciences:2
  Electrical engineering, electronic engineering, Information engineering:1
  Mechanical engineering:1
  Medical engineering:1
  Environmental engineering:1
  Interdisciplinary:1
- Number by Type
  Education Oriented:14
  Research Oriented:12
- Number by Ownership
  Fully or mostly public:26

Government/Intergovernmental Organisations except Higher Education:5

- Number by Level
  European Union - EU:1
  Central and Federal Government:3
  International:1
- Number by Type
  Government department or government-run general public services:3
  R&D Funding and/or R&D Performing bodies:2

Business enterprise:2

- Number by Market sector of unit of affiliation
  Electricity, Gas, Steam And Air Conditioning Supply:2
- Number by Type
  Private enterprises:2
- Number by Ownership and International Status
  Independent Enterprise:1
  Enterprise owned by a national group:1
- Number by Size
  Large company:2

COST Country Institutions(12) : Bulgaria , Czech Republic , Denmark , France , Germany , Hungary , Italy , Norway , Poland , Spain , Switzerland , United Kingdom
Near-Neighbour Country Institutions(1) : Russian Federation
COST International Partners(2) : Australia , United States
European Commission and EU Agencies(1)
European RTD Organisations(0)
International Organisations(1)

Network of Proposers - Details

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