

Usefulness of Simulating Social Phenomena

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Abstract. This paper discusses the current usefulness and implications of developing research on agent-based Simulation Models of Social Phenomena (SMSP) beyond purely academic, hobbyist or educational purposes. Design, development and testing phases are discussed along with issues evidence-driven modellers often face whilst collecting, analysing and translating quantitative and qualitative empirical data into social simulation models. Methodological recommendations are discussed in light of the importance of developing research besides its own theory.

1 INTRODUCTION

Various methodologies to model and simulate social phenomena are becoming increasingly popular as research disciplines, especially in academia but also –to a lesser extent– in industrial and commercial environments. In this sense, particular attention has been given to agent technology for building SMSP [29]. Besides much criticism to over-simplifications often found in models strictly based on keep-it-simple principles, many are still developed without guidance provided by analysis of evidence acquired in fieldwork [13]. It is essential to consider that social behaviour is often subject to many influences that are usually poorly understood without detailed datasets about the phenomena in question. Simplistic models often use unrealistic assumptions about the structure and processes of studied social behaviour, a fact that further complicates cross-validating social simulation models at macro and micro levels [20]. Such quasi-idiosyncratic practice seems particularly evident in social simulation models using personal estimations to justify arbitrary implementation decisions and parameter configurations. Considerable difficulties are, of course, imposed by common unavailability of statistically relevant data about social phenomena. Often these datasets are (a) simply non-existent, hence requiring funding to collect and process information, or (b) unavailable due to privacy agreements or, (c) when at hand, are typically incomplete or outdated.

Research on SMSP has arguably not yet progressed enough to overcome barriers in obtaining data and improve representations of social behaviour. Nor developed social simulation models pragmatically useful to stakeholders or policy-makers. These difficulties, along with other historical factors, have contributed to a research status quo that to date has:

- (i) No effective development-cycle methodology focused on producing results that are useful beyond academic theories,
- (ii) Numerous models based on loose evidence that often bears little relation to the real social phenomena in question;
- (iii) And disseminates a general sense of failure that simulation models of social phenomena can provide practical advantages or somehow become useful tools to stakeholders (or policy-makers).

Nowadays most practical applications from simulations of social phenomena are clearly centred in the educational, or intellectual, entertainment realms. Game-like models, e.g. MapleStory.com, NobleApe.com, TheSims [15], SpiderLand.org, SecondLife [16], BeyondSpaceAndTime.org and life.ou.edu/tierra/ have been popular in the game and artificial life (A-Life) niches. Yet these are clearly not intended to research topics of stakeholder or policy-maker interests. Using simulation models as entertainment businesses does not necessarily converge with improving the understanding of real, non-virtual social phenomena. Though agent-based models have gradually been consolidated as an alternative approach to traditional social sciences methods, insofar as no social simulation has provided contributions to policy-makers beyond hypothetical scenarios for them to consider.

In addition to these problems, the research community has generally neglected security of potentially sensitive data used for modelling and applicability of social simulations. This includes procedures employed in data collection, analysis and storage, plus the responsibility modellers have to emphasise the present-day unreliability of validation methods for assessing their own results. Theoretical potential of social simulation models have been arguably overshadowed by their foreseeable disadvantages. This is important, as there have been suggestions that SMSPs could be used to support or guide decision– and policy-making. This might only be possible with the aid of in-house experienced modellers working with stakeholders and policy-makers, but clearly not by them coping with the numerous interface limitations of running and interpreting non-trivial results obtained in these simulations.

Entertainment oriented SMSP, i.e. games or A-Life, are probably the only –if any– software similar to social simulation regular computer users are aware of. Yet, it can be difficult to distinguish the purposes of certain academic models from purely educational, or commercial, social simulations. Despite noteworthy progress in developing participatory modelling methodologies (i.e., those involving users directly throughout the research process) and simulations guided by evidence, impact in the wider community is barely perceptible. It is still unclear in the community what can be achieved, apart from theoretical discussions and illustrations, by analysing social simulations results that are not comparable with existing real social phenomena evidence. Assessing to which extent SMSPs meet their aims and objectives beyond theory is usually an experimental process of many trials and errors.

Given the broad scope of researchers' backgrounds working on SMSP, there is a natural diversity of methodological aspects to be considered in this area. However security regarding social data and applicability of simulation models has not been much addressed. Except participatory models, or those with immersive or augmentative environments, simulations do not require direct human participation. Though, modellers often process sensitive

data about them. These might include coding non-anonymised behavioural data and attributes, collected via questionnaires, oral interviews, mailing lists, online forums or social networking databases. Are these data storage and distribution procedures covered by any professional code? There is almost no guidance on what is acceptable in terms of using sensitive data for social simulation research. At best only institutional recommendations are in place, but these usually do not address data provided to and derived from social simulation models whatsoever.

2 SOCIAL SCIENCE AND SMSP ISSUES

Qualitative research methods for studying social behaviour have been traditionally linked with psychology, anthropology and other closely related disciplines to the social sciences. Since the Milgram and Stanford Prison experiments, conducted between 1960's and 1970's, there has been pressure for higher ethical standards and responsibility for testing social research hypotheses directly with human beings [21, 22, 28]. Despite disastrous consequences, these studies provided some important insights, such as behavioural enquiries on differences how humans behave *in situ* and in a controlled ambient. Methods employed in these projects are now deemed unacceptable, not only ethically but methodologically too due to issues such as selection biases.

Just as in psychology, anthropology also has relevant examples of unregulated research combined with unrealistic assumptions leading to numerous negative implications. Perhaps most notably is anthropological research funded with political and military purposes, particularly those motivated after the 9/11 unrest. Controversy relating social science ethics and social data harks back to colonial roots of anthropology in late XIX and early XX centuries. Examples include United States counter-insurgency undertakings employing anthropologists militarily in Project Camelot during 1960s and Operation Condor in the 1970s in Latin America, Cold War projects [9, 27], [Terrorism] Futures Markets Applied to Prediction in 2003 [44] and 2006 Human Terrain System (HTS) about Iraq and Afghanistan [8]. Despite clashing with their own codes of ethics [4, 5, 24], researchers in these projects remain a potential harm to themselves and others.

Similar problems can affect researchers in other circumstances. E.g., failure to caution technical unreliability of modelling and validating simulations that influenced decision-making for mitigating the United Kingdom 2001 foot-and-mouth disease outbreak [32, 23]. Quantitative simulations are dependent on good quality quantitative historical data in order to be useful in studying plausible approximations to what is the actual reality. I argue that analysis of good qualitative datasets and discussion with stakeholders is equally critical to guide development of social simulation models. Every social phenomenon has unique characteristics, so inevitably modellers must take into account these specifics on a case-by-case basis. Otherwise, why bother justifying representation assumptions and result interpretations coherently according to grounded evidence? This is particularly relevant when physical or geographical features constrain processes in social phenomena. As then, it is clear modellers must represent these accurately with the guidance of relevant data. Validating the correctness of social simulations is difficult, as events that might play key roles in real phenomena may not have been modelled due to the lack of evidence or knowledge. And without it, modellers can only be guided by academic theories,

personal intuition or hunches. If regulated professions struggle with enforcing ethos, consider areas where research conduct is unregulated. Computer research in some countries can be problematic in this regard, as ethic codes are law binding if professionals are voluntarily subscribed to organisations such as Association for Computing Machinery or Institute of Electrical and Electronics Engineers [6, 7]. Despite being the largest hardware and software professional associations, enforcing codes against research malpractice is limited, as these recommendations are often not formalised in local institutions.

Information technology certifications are commercial titles and contrasts with professions supervised by legal regulatory bodies. The former has only superficial ethical standards on negligence or fundamental mistakes in using sensitive data. One must be fair and acknowledge that insofar as a minority of simulation models have used detailed behavioural datasets that could be classified as sensitive. Perhaps this is a side effect of the little utility these models insofar provided beyond academia. Though as guiding simulation development and comparing results with evidence strengthens as a research trend, it is likely that current standards improve for dealing with data and interpreting simulation results. Particularly with regards to methodological aspects to represent social structures, processes and behaviour in light of evidence.

Social simulation modellers could follow adaptations of relevant aspects already existent in social science codes of ethics. This must not confuse with good practice recommendations related to humans interacting with immersive virtual environments such as HTS, Virtual Milgram [27] or other Internet services where users assume digital identities using customised avatars. Instead, the argument hereby focuses on development and validation of social simulations using evidence, running with or without direct human participation. The intention is to highlight ethics during the research process from design to evaluation phases of SMSP, as models built with unfounded evidence can ultimately become counter-productive. Research on SMSP is better guided by using grounded evidence, as modellers can improve assumptions and representations according to detailed understanding of the social reality. Still, many social simulation models are built without detailed qualitative and quantitative analysis of representative data. Whilst practical advantages to policy-makers provided by social simulation models are to date inexistent, theoretical discussions abound. Although helpful to further some academic knowledge, most of this is useless to stakeholders or policy-makers interested in influencing somehow social phenomena.

Evidence is a requirement for doing social simulation research that ought to be useful both to academics and policy-makers, as it is essential that modellers have a good understanding of their study cases. This helps to identify relevant parameters and estimate configuration values backed by real data. Which, in turn, also provides comparable reference to what has been obtained in simulations. Otherwise the modelling process would be guided solely by socio-theoretical academic frameworks, which usually require several arbitrary implementation adaptations due to their abstract nature. Issues of improving translation of qualitative data into computational processes and structures have not been discussed much. Most simulations source codes are not available and papers discussing these commonly fail to describe models in enough detail for allowing proper replications. SMSP requires cohesive data interpretation; otherwise one risks speculative assumptions that are not backed by evidence. This problem is to

some extent comparable to issues in social science involving ethics and research purposes. SMSP have yet to offer clear advantages to stakeholders interested in influencing or better understanding real social phenomena. Model validation is a major problem, as even simulation models using quantitative and qualitative evidence are subject to risk assessment difficulties.

There seems to be just one code of ethics specifically targeting research of simulation models [38, 39]. Items 2.6 to 2.8 in that document, addresses the professional competence issues hereby discussed. This includes the responsibility of presenting clearly the applicability of social simulation models and interpretation of their results in light of unbiased evidence. Till early March 2009, none of relevant research associations, namely European Social Simulation Association (www.essa.eu.org), North American Association for Computational Social and Organization Sciences (casos.cs.cmu.edu/naacsos) and Pacific Asian Association for Agent-based Approach in Social Systems Sciences (paaa.econ.kyoto-u.ac.jp), has a single institutional document on research ethics of what they represent. Since its first volume in January 1998, the Journal of Artificial Societies and Social Simulation (jasss.soc.surrey.ac.uk) has published only one article tangentially relating ethics, responsibility and accountability, but of simulated agents and not researchers themselves [40].

4 SIMULATION RESEARCH vs. GAMES

Most academic simulation models of social behaviour do not have an elaborated user interface, as it is usually unnecessary: researchers themselves usually run them, not regular computer users. Computer games are the opposite: visual appeal is one of their most important and marketable features. However, some simulation models can resemble video games. Not from playability or graphical perspectives, but from the usefulness perspective. E.g., educational games focused on delicate topics, such as warfare titles Madrid, Sept. 12, or HIV contagion [37], are just simple online animations. Some role-playing games can be considered simulations without research aims; titles such as: Peacemaker.com modelling turn-based peace strategies between Israel and Palestine, United Nations crisis mitigation at FoodForce.com, Janjaweed militia attacks at DarfurIsDying.com, social unrest in Mexico and Jerusalem at GlobalConflicts.eu, defence of Islamic states at QuraishGame.com, dictatorships in AForceMorePowerful.org and commercial military training using VirtualBattleSpace.com or the previously mentioned HTS.

None of these examples used academically grounded evidence to guide or justify their implementations. One may argue that it was not needed, as their focus is simply to illustrate aspects of some much more complex phenomena for educational purposes. Should academic research on SMSP follow suit and simply raise awareness as these game-like simulations do? There must be fundamental differences in terms of how academic researchers doing social simulation build models and apply their results. Otherwise not much else can be done beyond fuelling theoretical discussions or what these games already provide. This issue is perhaps clearer in models designed for contributing to policy-making processes, as validation of simulations results without empirical data is just speculation. Research models and games can provide illustrations inspired in real events. The problem is that it is relatively easy to build mechanisms into these systems to influence results according to whatever arbitrary property one

may wish to observe. As simulations source-codes are usually unavailable, model scrutiny is limited to relying on individual honesty. Without grounded evidence or accurate representation, simulation models can indeed contribute to misinterpret real social phenomena. Implementing SMSP is not equivalent to translating social theories into software, and acquiring knowledge about simulation models is not necessarily relevant to understand the real social phenomenon in question. Whilst some argue that social simulations can clarify sociological theories, others contest this by arguing that what actually helps is the *process* of formalising knowledge (i.e. representing assumptions without ambiguities or vagueness) about social phenomena, and not simulation results *per se*. It is important to differentiate which questions are relevant to understand the real social phenomena from those that are only useful do deal with a computer model.

Educational games and simulations have clearly been an increasing topic of interest not only to academics but for regular computer users too. The research network SageForLearning.ca differentiates these types of software between serious educational games and research models. The former is defined in [41] as containing all the following indispensable attributes: static rules for conflict resolution, players as decision makers, conflict-cooperation strategies, an educational script associated with goals and fictional characters. Despite controversies on their efficacy [42], learning is promoted as an experimental entertainment in a controlled environment [43]. Research models are defined in the same document as having a limited, yet *accurate*, representation of reality that *is able* to generate results comparable to existent data and that *necessarily* mediates acquisition of new knowledge about the actual social system via simulations. In other words, SMSPs require evidence, as otherwise one would not differentiate models providing approximations of real social phenomena from simulations that mediate acquisition of new knowledge about a given social reality via simulations. A better understanding of simulation models is not necessarily relevant to stakeholders or policy-makers. If modellers are unable to validate results, chances are that only fieldwork findings will be regarded useful by them.

5 SIMULATION MODEL'S LIFE CYCLE

Models of social behaviour are nowadays arguably only really useful to stakeholders as a test platform of hypothetical scenarios configured with the aid of specific empirical datasets. Results can be interpreted by domain experts and assessed to which extent those are helpful. In academic terms, apart from analysing design, representation and simulation technicalities regarding effects of combining different parameters, models are assessed by their maintenance and by comparing results obtained in simulations with evidence and stakeholders' understanding of outputs such as in [18, 20]. In synthesis, SMSP are useful to generate synthetic data based on some aspects of real social systems. These, in turn, may lead to new lines of enquiry on how to further develop a model or, in some rare cases, shed new light on the assumptions to understand the real social phenomena. Once models reproduce plausible results based on existing evidence, validating outputs that have no comparable datasets is an eminent issue that seems only properly clarified by comparing simulations with new data. There has been methodological progress, but relevance is largely theoretical and reliability of validation procedures is incipient. SMSPs are discussed far more in theoretical, or technical, terms and expectations than by means of practical applications [43].

Though it has been suggested that interpreting models output one might improve understanding of real social phenomena, in fact, pragmatically useful findings to stakeholders still tend to be findings of scrutinised fieldwork evidence, not simulation results.

Simulation platforms are useful for testing configurations, but there are crucial methodological difficulties to assess the real usefulness of results obtained from social simulations. Take for instance the influence of coding techniques. Each of these will lead to implementation of social behaviour and its processes according to a paradigm's limitations. Fully procedural, or object-oriented, models usually represent data as numerical properties and thresholds that are often controlled by sequential processes². These reinforce positive or negative feedback loops, which often contain commands for altering and logging monitored numerical properties. Update frequency can be dependent on how long a simulation will run and whether thresholds are static or dynamic at runtime. Analysing the correlation between initial parameter configuration and simulation results can shed new light on understanding predictable model path-dependency properties both at micro (individual) and macro (collective) levels. This is why it is worth analysing how sensible a model implementation is with regards to using different simulation parameter values.

Most agent-based simulations include these structural features, even those using declarative implementations for backward or forward chaining data processing. In this case information is manipulated according to a symbolic order given by resolution strategies involving constraint satisfactions, such as the Selective Linear Definite (SLD, and its extension SLDNF to deal with negation as failure) in Prolog [30], or the pattern matching Rete algorithm available in production rule systems such as JESS [31]. Thus, a declarative model will not only have procedural feedback loops in simulations, but also another introduced by one of these algorithms. Checking the consistency of these representations is important to ensure that models have coherent implementations with regards to the guidance provided by the analysed evidence. Otherwise these datasets would have been of limited usefulness.

Advantages of declarative models over procedural ones arguably include the fact that: knowledge is represented in a syntactical form which is easier to communicate directly with stakeholders, as facts and rules databases can be altered without modifying procedural control structures. This can be especially useful for maintenance purposes, as not much effort would be required to update existing rule and fact bases as fully procedural or object-oriented simulations. However it is unclear how declarative techniques actually contribute in terms of helping SMSP results more pragmatically useful. And, thus, if the extra technical effort involved in integrating these with existing simulation frameworks bring any concrete advantages to stakeholders. Three of the most popular agent-based simulation toolkits, viz.: Repast, Ascape and NetLogo, can take advantage of parallelism if modellers use some of specific Java libraries. It is important to point out that agent-based simulations often use algorithms dealing with numerous objects requiring little processing per cycle, which has less scalability potential [33] than those models where agents require more computing and storage resources to execute their tasks per

² Time-division concurrent multiplexing, i.e. one of the usual multi-threading technique used in single core processors, is not equivalent to parallel data or task execution found in computer architectures with multiple physical, or multi-core, processors and distributed memories.

defined simulation time tick. The latter statement holds, except when frequent communication is needed between most of agents at runtime. Distribution, on the other hand, is usually more suitable when entities' behaviours do not need to exchange numerous frequent messages over slow computer networks.

Detailed design and implementation of these features can only be currently be dealt with on a case-by-case basis. The previously mentioned application-programming interfaces (APIS) provide only basic and general functional structures that modellers must adapt to their specific needs. E.g., the `@ScheduledMethod` Java scheduler annotation in the latest Repast Symphony (version 1.1.0) iterates over all objects (agents) calling methods associated with it and executes them as threads of a single-program. As the default API does not oversee any particular concurrent or parallelism issue, modellers must ensure avoiding problems like concurrent threads not being able to use cores at runtime. Parallel agent-based models are currently largely the subject of experimental research, as experience in effective design and execution in this paradigm is less mature than in sequential, single core, simulations [34, 36].

Albeit relevant, no published in-depth comparison between models implemented –or replicated– in procedural, parallel and declarative paradigms seems available. Agent models of social phenomena may easily lead to unrealistic representations, not only structurally but also behaviourally. Fully reactive or rational social agent models have been notorious for inconsistent results when compared to social data [35], and sometimes problematic to replicate too [10, 11, 12]. Thus it is irresponsible to suggest that agent-based simulation models suffice for prediction purposes of social phenomena. Nevertheless, many simulation models are discussed as exploratory tools; even when essential evidence is unavailable.

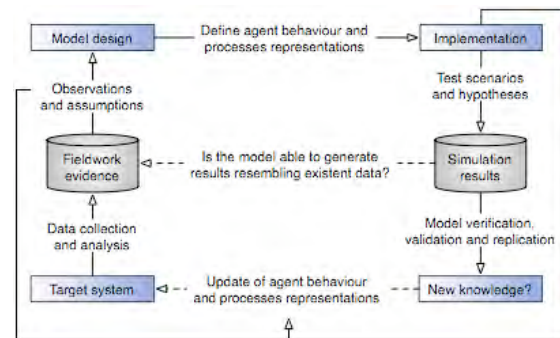


Figure 1: Typical life cycle of evidence-driven simulation model

To clarify the involved processes and their relationships during a model's life cycle, refer to the illustration above whilst reading the following explanation. The target system represents an actual social phenomenon being researched, from which evidence should be collected and analysed. Once the first phase of this crucial step is done, modellers can discuss the plausibility of relevant observations and assumptions with stakeholders and policy-makers. This is a potential loop as both researchers and domain experts in the social phenomena must reach a common understanding of what has been analysed and whether hypotheses are based on realistic assumptions. Only at this point evidence-driven modellers design the simulation, as otherwise no evidence (real data) would be available for verifying and justifying how the

model has been built. It is critical for modellers to differentiate what are essential parts of a model from what is contextual information about the social reality. I.e., some data is necessary to understand the social phenomena, but may not be relevant to include in the model. The latter obviously comprises much more information than the former, so it is important for modellers to clearly justify their decisions in deciding how to classify data in these categories. Arguably such detailed knowledge can only be realised via a combination of analysing grounded evidence and discussing findings with domain experts directly participating in the social phenomena. Evidence might be provided to modellers by third party sources, but it is still necessary to establish a common understanding of this data regarding experience with the real social phenomena. Many potential misunderstandings are clarified in this process, as unintentional oversights of important details may persist if modellers do not interact with relevant stakeholders and policy-makers. Technical representation of social behaviour evidence and their processes is a personal decision, as no thorough comparison between paradigms exists. The most popular approaches use one of the aforementioned object-oriented frameworks without declarative integrations.

Having built a simulation according to the guidance obtained from analysing evidence, modellers proceed to test hypotheses using scenarios resembling some characteristic observed in the real social phenomena. With results logged separately, it is time to compare simulations with evidence and discuss the findings in detail with domain experts (policy-makers and stakeholders). In case simulations consistently diverge from what has been observed in reality, it is likely that some of the representations have been incorrectly implemented, or that parameters have not been set realistically. The model should be adapted till is able to generate results that are both comparable to available evidence and deemed acceptable by stakeholders and policy-makers. From this milestone onwards modellers test simulations aiming at *mediating* the acquisition of new knowledge about the real phenomena by interpreting simulation results. To date the authors have not yet found a single example of a social simulation model that has been pragmatically useful to stakeholders as fieldwork findings can be. This has not been found in literature review and it has been confirmed by interviewing a number of researchers³. This happens partially as the context of many social phenomena change rapidly, hindering the accuracy of simulation models. Fieldwork analysis has nowadays far greater chances of being timely useful as it is feasible to provide stakeholders and policy-makers with up-to-date reports about specific aspects of the social phenomena in question that might still be occurring. Conversely, simulation models usually operate in much longer time scales and this creates serious difficulties in interpreting their inaccuracies.

Social simulation models should ideally be replicated, using the same or different computer paradigms, and compared to whether results achieved originally are consistent with the later versions. If modelling one social phenomenon alone is usually demanding enough to the point of preventing pragmatic applications, one should consider the complications of adding extra unnecessary complexity like nesting simulation models. In technical terms, this is not difficult, but this adds considerable complexity to evaluate results obtained in these models. A-Life and other virtual

reality systems have long been exploring this by integrating in one virtual world perhaps several parallel or concurrent models. E.g., some evolutionary A-Life biochemical models depend on the simulation results of another artificial model of environmental conditions. Of course this paper is not focused on these, but that is a good example of when validation issues do not matter. Research on SMSP must address validation and verification issues from the evidence analysis phase, as the whole point is to study real social phenomena via meaningful simulation models and not computer dynamics of virtual realities.

With the present state-of-the-art it is probably impossible to use simulation models of social behaviour for plausible prediction. Real social systems are undoubtedly more complex and volatile than any simulation. Although no model is absolutely correct or complete, guiding modelling and implementation with up-to-date evidence can considerably improve chances of developing more plausible and useful simulations. SMSP are by no means correct explanations of social phenomena, or their emergent properties, and to date at best offer illustrations based on existing evidence.

7 FINAL CONSIDERATIONS

Agent-based modelling is powerful to study dynamics of systems with multiple interacting entities and their non-linearity. This does not mean that social behaviour and structure can always be accurately represented in such simulation models. There is a pressing unfulfilled need for providing practical advantages to stakeholders via simulation results. This paper highlights the need for improving methodologies for applying SMSP results and for institutions to adopt existing social science ethical standards when computer simulations deal with sensitive data.

Even in simplistic representations, intellectual games, structured according to deterministic behavioural rules, can achieve their educational purposes. Currently most research in SMSP is not useful beyond academia –even when these are developed with the guidance of grounded evidence. Fieldwork analysis, on the other hand, is. There are significant methodological problems without solutions on validation throughout a model's development cycle. Besides, numerous institutional ethical assessments do not take into account use of sensitive data in this research area. Deficient research methodologies combined with the relative facility to develop models that are neither games nor useful simulations *per se* is linked to the lack of pragmatic uses of this type of software. This does not imply that social simulation researchers should see stakeholders as clients, but simply highlights how little this type of research has contributed beyond academic theories to date.

Experience in engaging stakeholders and policy-makers has shown that they are not interested on how social phenomena is modelled, but rather on which contributions this research process can provide. Persisting methodological difficulties that hinder credibility of SMSP include: (a) How can simulation results providing data beyond comparable existing evidence mediate acquisition of knowledge about a certain social phenomenon, (b) Which contributions SMSP can provide to stakeholders apart from illustrating hypotheses only verifiable with more data?

Without reliable validation methods and evidence, policy-makers tend to only take onboard findings obtained in fieldwork analysis.

³ To date, data is still being collected so an in-depth discussion of these findings can only be presented in a follow-up article.

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