THE REPRESENTATION-USAGE-IMPACT (RUI) METHOD TO BETTER FRAME THE POTENTIAL SOCIAL IMPACTS OF A HIGHLY DISRUPTIVE PRODUCT—APPLICATION TO THE AUTONOMOUS VEHICLE

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ABSTRACT

Innovative products can be highly prospective and apt to disrupt usages profoundly. They can lead to multiple long-term social impacts influencing people's way of life and behaviour. So it is necessary to anticipate them without delay. Due to high uncertainty, designers may face the problem that conventional user-centred methods, which assess design performances from today's users, are not adapted. We think sociologists can help characterise the likely social impacts of future products. So we propose an original framework called the Representation-Usage-Impact (RUI) method to stimulate sociologists' projection and capture relevant knowledge about probable social impacts. The method includes a database structure encoding the knowledge of sociologists for further use in the design process. Its goal is to help designers avoid making choices today that may be regretted in decades. We illustrate the method and its process with the design of autonomous vehicle scenarios, as it will likely bring many new usages in the future. As the method is still under construction, we present an intermediate validation step involving sociologists. The first results suggest that the method might be a safeguard for the design of disruptive products.

Keywords: Design methodology, Societal consequences, Impact assessment, Innovation, Future

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Cite this article: Lecomte, R., Yannou, B., Cahen, R., Thibaud, G., Etienne, F. (2023) 'The Representation-Usage-Impact (RUI) Method to Better Frame the Potential Social Impacts of a Highly Disruptive Product—Application to the Autonomous Vehicle', in *Proceedings of the International Conference on Engineering Design (ICED23),* Bordeaux, France, 24-28 July 2023. DOI:10.1017/pds.2023.346

1 INTRODUCTION

It is in the interest of companies to anticipate the social consequences of the products they are about to launch. For this, some methods can be essential when a product is highly suspected of disrupting usages and everyday life experience. Within our research framework, we were interested in the specific case where the product would be deployed in the long term (several decades) but for which the suspicions of disruption would be high. From a responsible innovation perspective, this means anticipating the impacts of a future product at a very early stage to avoid generating undesirable and sometimes irreversible consequences. Although some product evaluation methods use the term usage performance, we prefer the term impact, which is more suited to long time scales. But at these scales, the high level of uncertainty prevents anticipating any social phenomenon in advance. For example, the smartphone generated numerous long-term social impacts, such as the deterioration of attention among the youngest (van Velthoven et al., 2018). We can imagine that anticipation at the early stages of development could have diminished this now-irreversible problem. This raises the question of how to characterize the likely social impacts of a disruptive product that does not yet exist. We focused exclusively on social impacts as defined by Burdge (2015): "The influence of a product on the day-to-day quality of life of persons." We considered individuals, groups, and the entire population (multi-stakeholder approach).

In the design science field, some evaluation methods can anticipate the social consequences of a new product. A typical design process can be divided into three macro-steps: Discover, Design, and Evaluate (e.g., design thinking (Brown, 2008) and V-cycle (ISO 26262-1, 2018)). The Evaluate part allows performances to be measured. One product evaluation category is User Acceptance Testing (UAT), which seeks to validate the relevance of the product to the user. To quote Herbert Simon in The Sciences of the Artificial, the goal is to "transform existing situations into preferred situations" (Simon, 1996) for the targeted user. It is, therefore, common to find evaluation methods involving users to measure the effective use of the product, its good understanding, and its contribution. Jørgensen (1990) explains, "Users' knowledge is different from designers' knowledge." Thus, methods involving users help designers to limit their biases and fixations regarding the real use of the product. Among existing methods, we can mention analogies (Davis, 1985; "Startup Cemetery," 2022), focus groups (McQuarrie and McIntyre, 1986), heuristic evaluation (Nielsen and Molich, 1990), usability tests (Dumas et al., 1999), purchase intention or multi-attribute models (Green and Srinivasan, 1990). Yet, user acceptance methods are often limited to evaluating short-term performances such as comfort, ergonomics, or user experience. This is usually sufficient for a short-term deployment or a product upgrade. However, when the deployment date is extended, the product's characteristics become uncertain, and test participants become less representative of future users. Even if some design approaches, such as Radical Innovation Design (Yannou, 2015; Yannou et al., 2018) try to consider this aspect, product evaluation remains ill-suited for characterizing or assessing long-term social impacts.

Beyond the evaluation of a simple product, impact assessment methods try to assess the impacts of large-scale interventions like policy measures or new technologies deployment. These are often used in policymaking, considering broad consequences on the environment, people, communities, social well-being, culture, economy, or health (Becker, 2001; Understanding Impact Assessment, 2020). For instance, the Intergovernmental Panel on Climate Change (IPCC) reports are considered impact assessment reports. More specifically, social impact assessment (SIA) methods help identify an intervention's future social consequences to achieve a more sustainable and equitable environment (Becker, 2001; Vanclay, 2003). SIA can also be generalized to society (Kreissl, 2015). Other approaches, such as technology assessment (TA), specifically examine the short and long-term consequences of deploying a new technology (Arnstein, 1977; Banta, 2009; Coates, 1974) and can serve as decision-making tools. Unlike product evaluation, these methods allow for identifying and considering various impacts over varying time scales (Epstein and Yuthas, 2014; Fontes, 2016; Vanclay, 2002). However, they are relevant when planned actions are well defined or even already engaged and when the targeted population is known. These observations lead to the "Collingridge dilemma" (Collingridge, 1980): At the beginning of the development of a technology, its nature and how it will be used are still malleable, so its impacts cannot yet be precisely determined. The technology is already well-established when the consequences become apparent, and it becomes too difficult to change.

To summarize, product evaluation methods apply to well-defined products, affect known users, and are suited to assess short-term consequences like ergonomics, comfort, or user experience. On the

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other hand, impact assessment methods, like social impact assessment and technology assessment, consider broader and long-term social impacts but are still limited to well-defined planned actions (policy measures, new technologies) that concern a known population.

These two families of methods seem limited to dealing with the long-term social impacts of a disruptive product that does not exist. To address their limitations, we hypothesized that the best way to get insights about the likely social impacts of a product with so many uncertainties was to rely on sociologists. The underlying assumption is that social sciences can be applied to unknown future environments. This led us to develop an original method that helps sociologists project themselves in disruptive usage situations to evaluate a new product's potential social impacts. The knowledge generated by sociologists is then stored in a database system to be used by designers. The method's goal is neither to predict the future nor to provide proven causal links between a product and its long-term impacts. Instead, the goal is to get designers or decision-makers to ask questions about the impacts that a specific design choice could generate in the long term.

As the RUI method is still under construction, we present in this paper an initial version focused on the autonomous vehicle (AV) case study within a major automotive group (section 2). To test whether our proposition has the potential to generate sociologically consistent impacts, we detail a protocol to let sociologists evaluate the method (section 3). We then present their feedback (section 4). Finally, we summarize the limitations of the initial version and propose leads to address them. We also discuss the method's potential to answer our main question about how to characterize the likely social impacts of a disruptive product that does not exist and present the next steps (section 5).

2 METHOD DESCRIPTION

2.1 Case study

The initial version of the method was developed for the specific case of the autonomous vehicle (AV) within a major automotive group. We started with the following definition of an AV: A vehicle evolving on the road that can carry passengers and drive itself without any human intervention (inspired by "What is an Autonomous Vehicle?" 2021). As this definition remains very generic, we added four conditions: (1) The vehicle is designed to transport passengers in priority. It can transport objects, but this should not be its primary function. (2) The vehicle has 1 to 9 seats (category M1 from United Nations Economic Commission for Europe, 2017). (3) The vehicle has an automation level of 4 or more on the SAE scale (SAE International, 2021). (4) The vehicle operates in a country with a high human development index (≥ 0.700) (Gibbs, 2022; UNDP, 2020). We also set 2050 as an approximate time horizon (ERTRAC, 2019; Gartner, 2020).

2.2 General principles

The assumption behind the method is that sociologists can anticipate some probable long-term social impacts of a disruptive product that does not exist. This implies that social sciences knowledge about past phenomena can be applied to assess future phenomena. The method aims to help designers make good choices in designing future products. Therefore, we have focused on sociologists' interviews, knowledge storage, and access. As a future disruptive product, AVs will likely generate usages leading to significant social impacts. These usages are challenging to predict, but it is possible to imagine them. Many people have done so, from car manufacturers to science fiction writers. This led us to our main idea: present specific usages of AVs to sociologists specialized in chosen social themes (see section 2.7) and ask them to think about the social impacts that could result. To populate a database with usages, we chose to extract them from existing representations of AVs, which are abundant in the literature, on the Internet, and among car manufacturers' public documents. The links between existing representations, usages and impacts are shown in Figure 1.

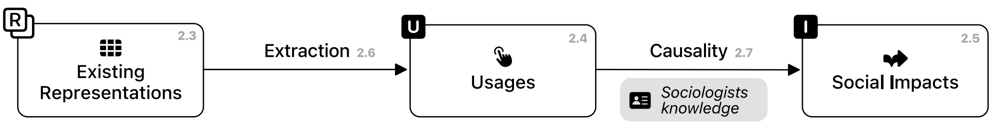

Figure 1. Elements and links used in the RUI method.

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We describe the constituent elements of the method in the following sections. We first define three ontologies for the representations, usages, and impacts (sections 2.3 to 2.5). Then we set up a protocol for extracting usages from representations (section 2.6) and a protocol for generating impacts with the help of sociologists (section 2.7). At last, we build a database system to store, exploit and update the knowledge (sections 2.8 and 2.9).

2.3 Ontology of existing representations

We present an ontology to store, sort, exploit and trace existing representations of AVs that can then be used to extract usages. Exploiting many representations of different natures and origins as input material for our method seems to be a good way of ensuring a large diversity of usages. This also avoids biases we would have introduced if the usages had come from our imagination.

A representation is a general category encompassing all types of artifacts, physical or virtual. It covers all types of externalization (Boujut and Laureillard, 2002). We have defined a representation by seven attributes (capitalized): (i) The reference NAME of the representation. (ii) The AUTHOR (company or person). (iii) The YEAR of publication. (iv) The RESOURCES to illustrate the representation (image, internet link, video). (v) A brief, factual DESCRIPTION. (vi) The SHAPE that can be: Design fiction object; Concept; Non-functional prototype; Functional prototype; Functional product; Film / TV series; Cartoons; Book; Internet article; Magazine; Comic book / Graphic novel; Software / Video game; Patent; Imagined usage. (vii) The MATURITY, inspired by Technology Readiness Levels. The higher the level, the more realistic the representation is: (level 1) Fiction: No willingness to be realistic; (level 2) Project / Vision: Willingness to be realistic but does not exist; (level 3) Real: Exists.

These attributes were determined inductively based on 70 existing representations of AVs found by internet searches or discussions with designers, engineers, or futurists. An example is presented in Figure 2 (left part).

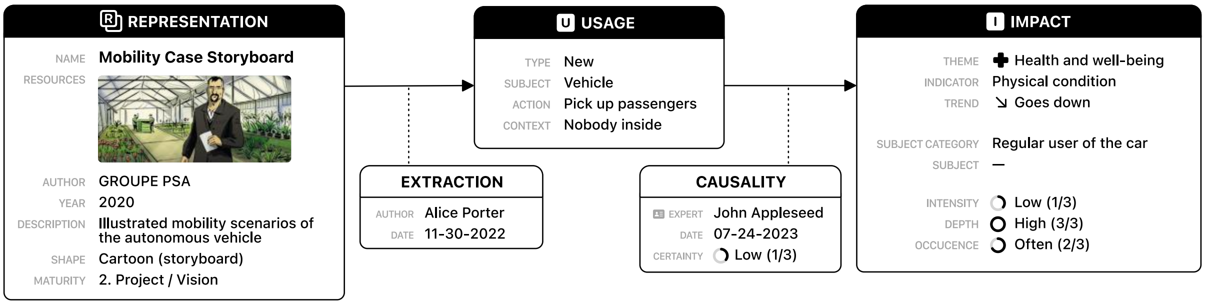

Figure 2. Examples to illustrate the attributes of the RUI method.

The protocol for adding a representation consists in (a) identifying a representation presenting at least one potential usage of the AV, then (b) completing the seven attributes related to this impact. We did not constrain too much the addition of representations since our goal was to obtain diversity in the usages. For more examples, an extract of the database is available online (see *additional resources* section).

2.4 Ontology of usages

Scenario approaches are known for addressing both complex and uncertain issues (Mcgrail and Idil Gaziulusoy, 2014). Many works on scenarios attempt to imagine the future of transportation (Gazibara, 2011; Hannon et al., 2016; Kaufmann and Ravalet, 2016; Urry, 2016). Other approaches focus on individuals and their experiences, such as Trommer et al. (2016) and Rohr et al. (2016), who imagine stories called "a day in the life of [...]." We think these approaches are suitable for anticipating human factors and the evolution of social structures. However, the uncertainty we face is not suitable for using detailed mobility scenarios (e.g., Fulton Suri and Marsh, 2000), which are generally adapted to known usages in known contexts. We use instead elementary steps called "usages," allowing us to focus on new usage situations exclusively (see Bekhradi et al., 2017). A usage is defined by the destination, function, or use that can be made of something (Larousse dictionary, meaning 3). Unfortunately, the subtleties associated with a full journey description are lost (see Al Maghraoui et al., 2019). However, with AVs, approaches considering a complete scenario would only add complexity without improving the plausibility of the scenarios.

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The usage ontology must provide a precise and consistent description of an AV usage situation and allow for stimulating the imagination of sociologists without ambiguity. We built it inductively with 26 raw usages identified within the 70 existing representations of AVs. After several iterations and implementing a mini-validation protocol involving four people (not detailed here), we defined four coding attributes: (1) The TYPE distinguishes (i) new usages from (ii) existing usages enhanced by AVs. (2) The SUBJECT is who performs the usage: the vehicle, one or several passengers, or external persons. (3) The ACTION field allows us to describe what is done by the SUBJECT. An action is an infinitive sentence describing a scene, a step, or an elementary task. It begins with an infinitive verb. Example: "Go get an object," "Work." (4) To render a new or enhanced usage, additional CONTEXT can be added. For example, for an individual, the action of sleeping inside a vehicle is already possible today, but if the action takes place during transportation, the usage is now enhanced. It is possible to specify one or more (logical AND). To better read usages, attributes 2, 3, and 4 present a logical sequence similar to a sentence: subject, verb, complement. An example of usage is presented in Figure 2 (center part).

2.5 Ontology of social impacts

The social impacts ontology was built to satisfy four conditions: (1) embed the subtleties mentioned by the sociologists, (2) be consistent with social science, (2) be understandable for non-experts, and (4) allow to add new social impacts frequently. We restricted our study to impacts generated during the use phase of AVs. For example, we do not consider the impacts of raw materials extraction or recycling. Impacts related to direct users' perceptions, such as motion sickness or lack of comfort, are not considered because existing product evaluation methods are better suited to assess them (see section 1).

Several methods can be used to describe impacts. Among others: the Logic Model (Practical Concepts Incorporated, 1979), the Theory of Change (Weiss, 1997), the Outcome Map (Earl et al., 2001), or the Impact Management Project (2022) (IMP). We chose to draw inspiration from the latter, which identifies a consensus of five dimensions for describing an impact: What, Who, How much, Contribution, and Risk (Fox and Ruff, 2021). As the dimension of Risk does not seem relevant at a high level of uncertainty, we used only the four other dimensions. We then subdivided the dimensions into a total of nine impact attributes. (1) The first dimension is called *WHAT* and is intended to make statements about what is happening. It includes three attributes: (i) a THEME inspired by Rainock et al. (2018) that identified a series of social phenomena influenced by products and technologies and proposed a group of 11 broad themes: population change, family, gender, education, stratification, employment, health and welfare, human rights, networks and communication, conflict and crime, and identity and cultural heritage. These themes (themselves inspired by Epstein and Yuthas, 2014; Fontes, 2016; Vanclay, 2002) seemed properly adapted for assessing medium- and long-term consequences of a product on people. (ii) The INDICATOR is a qualitative or semi-quantitative variable. An INDICATOR belongs to a theme. (iii) The TREND helps to characterize the evolution of the indicator: "increase," "decrease," or "no evolution." (2) The second dimension is called *WHO* and aims to qualify the individuals concerned by the impact. It consists of two attributes: (iv) The SUBJECT CATEGORY categorizes the subject using his socio-demographic and/or behavioral characteristics, and (v) The SUBJECT adds refined details. (3) The third dimension is called *HOW MUCH*. It includes three quantitative attributes that can take discrete values between 1 and 3: (vi) INTENSITY captures the impact's intensity level. It ranges from low to high. (vii) DEPTH captures the approximate share of people matching the subject description and affected by the impact. It ranges from few to all. (viii) OCCURENCE concerns the likely frequency of the impact. It ranges from rare to frequent. (4) The last dimension is *HOW* (derived from Contribution in IMP). It links the impact to one or more usages with the help of a single attribute: (ix) USAGES. These links will be further described in section 2.6. An example is shown in Figure 2 (right part).

The three ontologies we have just described must now be linked together. We distinguish two links: (2.5) extraction, which links a representation to a usage, and (2.6) causality, which links a usage to an impact (see also Figure 2).

2.6 Usages extraction

The extraction consists of identifying and then codifying a usage from a representation. This process can be followed by any person trained to use the method and does not require any expertise. To ensure data traceability, there are two attributes for each extraction: (1) the AUTHOR identifies the person

who extracted the usage, and (2) the DATE allows specifying its temporal reference. An example is presented in Figure 2.
To add an impact, we propose some recommendations: The first step is to identify a potential usage in a representation. The second step is to check its correspondence with the four AV conditions of section 2.1. It can be difficult to check these conditions because representations are sometimes incomplete. In this situation: If one of the conditions has a clear negative answer (e.g., the vehicle has ten seats), then the usage should be rejected. If all four conditions have no clear answer, it is allowed (but not recommended) to add the usage. If at least one condition has a positive categorical response and all the others do not have a clear one, it is recommended to add the usage. Finally, if the level of automation is not determined, it should be verified that the usage takes place in a vehicle with no driver.

2.7 Impacts generation by sociologists (causality)

The causality that links a usage to an impact is obtained by questioning one or more sociologists. Each is likely to have specific areas of expertise in mobility, education, territories, geography, urban planning, lifestyles, and/or social practices. Thus, selecting them to cover a maximum of areas is relevant. Experts that are not necessarily sociologists but who work on the Social Impact Assessment (SIA) or Social Life Cycle Analysis (S-LCA) (United Nations Environment Programme, 2020) may also be relevant because of their systemic vision of social impacts.
Three attributes help to ensure traceability for the causal link between usages and impacts. First, (1) the EXPERT identifies the sociologist and his area of expertise. (2) The DATE specifies the moment the sociologist generated this link. (3) The CERTAINTY consists of a quantitative self-assessment of the sociologist's confidence in his proposal. It can take values between 1 (very uncertain) and 3 (certain).
The addition of impacts follows two phases: Phase 1 is a semi-directed interview with a sociologist. This interview consists of (i) presenting the approach, (ii) presenting a series of usages, and (iii) following, for each usage, an interview framework with several questions like *What social impacts are likely to result from this use? Can you try to quantify the intensity of this impact? Can you approximate your level of certainty for this statement?* These questions are designed to facilitate the coding of impacts later. The advantage of conducting a semi-structured interview is twofold: the sociologist does not need to learn how to code an impact and can add whatever level of detail he wants. Phase 2 takes place after the interview and consists of coding the impacts from an audio recording and/or the notes taken during the interview. An example is shown in Figure 2.

2.8 Databases' structure

The three ontologies and the two links are structured in five linked databases to store the knowledge. The goal is to be able to consult and exploit it afterward. The databases' structure is shown in Figure 3.

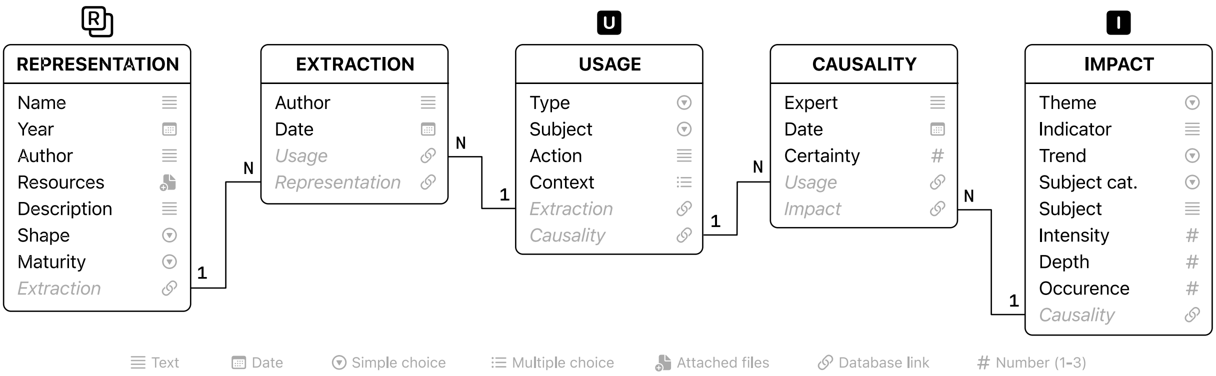

Figure 3. Structuring the method into five linked databases.

2.9 Consultation modes

The consultation modes allow access to the knowledge distributed in the databases. We defined two of them: (1) The causal mode consists of selecting usages to obtain a corresponding list of likely impacts. These usages may, for example, come from a scenario imagined by a designer for which he would like to see potential impacts. (2) The reverse mode consists of selecting impacts and obtaining a list of usages that are likely to cause them. For example, a designer could select impacts that he considers

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undesirable to learn about usages to avoid. For these two modes, the designer can select a single impact or a single usage to display the contextual elements related to it. For a usage, it is the representations from which it is extracted and the impacts linked to it. For an impact, it is the usages that are linked to it. A graphic interface is presented in a video available in the additional resources section to visualize how these consultation modes may be used.

3 EXPERT EVALUATION PROTOCOL

The initial version of the RUI method is built based on our knowledge, intuitions, and scientific readings. However, our choice to call upon social sciences can add various biases because our expertise is based on the design sciences. Therefore, we chose to involve sociologists to evaluate this initial version. To do this, we built a specific protocol: (1) identifying sociologists likely to provide constructive feedback on the method. We targeted sociologists familiar with transportation issues or experts on some of the eleven selected social themes (see section 2.5.1.i). To do this, we found people who had already worked with researchers in our laboratory. We identified several members of research institutes focused on the social aspects of transport (e.g., "Forum Vies Mobiles," 2022). We also conducted internet searches to complete our list of specialists. To save time, we created an online questionnaire that would (2) explain the method effectively through a short video and (3) give sociologists the option to provide written feedback directly into the questionnaire or to schedule a video call with us. As most of the sociologists identified were French, the questionnaire and the video are in the French language. They are available in the *additional resources* section.

4 EXPERT EVALUATION RESULTS

In a limited period of three weeks, twenty solicitations by e-mail allowed us to obtain four answers and five promises of answers.

The four experts who answered understood the method and the way it works. They all found it interesting. One of them wrote that the documentary analysis (representations) coupled with an exploration phase (extraction) was the right approach. Several limitations were raised at all stages of the method. For the representations, some explained that authors could lack subtlety by often choosing to describe utopias or dystopias. They also warned about the current states of mind of representations' authors that could introduce bias. For the usage extraction phase, they noted that usages were most likely to be built during the transition period (e.g., during semi-AVs' deployment that will precede fully-AVs deployment). They also identified that taboos and misuse of the product could be forgotten. For the impact generation phase, some experts explained that it was impossible to precisely link usages to impacts because the universe in which they occur is volatile, and users' constraints are unknown. Finally, one expert explained that if too few sociologists were chosen, we might face a selection bias.

5 DISCUSSION AND PERSPECTIVES

The initial version of the RUI method presented here is based on our hypothesis that the best way to obtain knowledge about the likely social impacts of a disruptive product that does not exist is to interview sociologists. After detailing the components of the method and our choices, we put it in front of sociologists to assess whether it could generate coherent social impacts. They first found it interesting but expressed some limitations: (1) The representations may lack subtlety and may reflect current states of mind. To account for this problem, we intend to (a) multiply the representations to get a nuanced set and (b) detail why, how and by who representations were imagined. (2) The method does not consider the incrementality that leads to a new usage. This limitation is assumed. (3) Taboos and misuses of the product may not be anticipated enough. Warning sociologists could prevent this problem. (4) Experts cannot link usages and impacts precisely without context. As the universe in which each usage will take place is unknown, this challenges our approach of directly linking usages to social impacts. One solution would be to add contextual elements (scenarios) for each usage-impact causal link. (5) User's constraints will evolve compared to today. It might be interesting to ask sociologists to imagine these constraints before imagining the impacts. (6) Expert selection bias can be substantial. It is, therefore, essential to multiply the number of experts to soften the bias. On our side, we identified four complementary limitations. (7) The choice to use elementary usages rather than complex mobility scenarios deprived us of anticipating the impacts that could arise from a chain of

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several usages. This limitation is assumed. (8) We did not develop the method as a full-fledged design tool adapted to existing design processes. Integration of the RUI method into industrial design tools could be the subject of a future research project. (9) The eleven selected impact themes from Rainock et al. (2018) are very generic and lack precision. In a future version, they could be better described and presented (e.g., UNEP, 2021). (10) Regarding consultation modes, when a query is formulated by selecting several usages, the results could present conflicting impacts: several impacts with the same indicator can be presented with redundant or contradictory attributes. As a solution, we could merge similar results by using classic data-analysis principles or advanced query methods like case-based reasoning (Riesbeck, 1989; Leake, 1996; Kolodner, 2014).

The absence of fundamental limitations does not validate the method, but it does encourage us to develop it further (Figure 4, step 5). We plan to add impacts by conducting twenty interviews with sociologists (Figure 4, step 6). This way, we will test our assumptions by evaluating the capacity of sociologists to project themselves into new usages. For that, we plan to count the number of impacts each sociologist generates and their certainty level. Then, we plan to verify whether the sociologists agree with each other about the impacts. This will also help to test our assumption that social sciences can be applied to environments that are not yet known. Last, we want to conduct a validation protocol involving non-experts to help characterize the method's consultation modes' usability and usefulness (Figure 4, step 7).

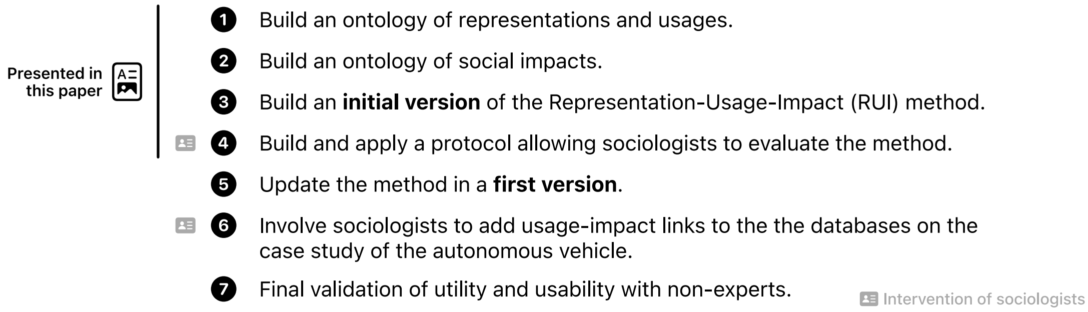

Figure 4. Macro steps for the creation and validation of the RUI method. Steps 5, 6, and 7 are remaining.

Existing impact evaluation methods are limited concerning disruptive products that do not exist, such as the autonomous vehicle. On the one hand, product evaluation methods concern known products and users and consider short-term consequences. On the other hand, impact assessment methods concern well-defined actions that concern a known population. The RUI method draws strong inspiration from impact assessment methods in considering both broad and long-term social impacts. Unlike these two families of methods, it does not aim to anticipate impacts precisely but rather to stimulate reflection by presenting coherent links between possible usages and social impacts. Its first originality is to compensate for uncertainty by drawing usages from many existing representations. The underlying idea is that since we cannot predict which usages will be predominant, we prefer to consider as many as possible. The second originality of the method relies on sociologists' expertise to generate coherent probable impacts from the usages.

Regarding our initial question about how to characterize a disruptive product's likely social impacts, we believe our proposal could provide some interesting answers. As mentioned, the RUI method still needs to be finalized, but the first observations we have been able to make through sociologist evaluations are encouraging. If the remaining validation steps are successful, we plan to use the method to create industrial design tools that could be tested in real conditions in a major automotive group.

ADDITIONAL RESOURCES

The following link leads to three additional resources: (1) an extract from the representation database, (2) a video demo of the consultation modes, and (3) details of the questionnaire for sociologists' evaluations with a link to the descriptive video.
https://iced2023-anonymous.notion.site/Additional-resources-2c4a9785898b4487bf1c0e27d5f12282

https://doi.org/10.1017/pds.2023.346 Published online by Cambridge University Press

ACKNOWLEDGMENTS

We thank the sociologists Isabelle Moussaoui, Magali Pierre, Laurent Fouillé, and Catherine Macombe, who agreed to respond to the questionnaire.

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