Design Science

AutoVision: Complementing designer judgment and exploring cognitive limitations in responsible autonomous vehicle design

Robin Lecomte[1,2], Bernard Yannou[1], Roland Cahen[3], Guillaume Thibaud[4] and Fabrice Etienne[4]

[1]*LGI, CentraleSupélec, Université Paris-Saclay, France*
[2]*CRD, ENS Paris-Saclay, Université Paris-Saclay, France*
[3]*CRD, ENSCI Les Ateliers, France*
[4]*Stellantis, France*

Abstract

Responsible design requires anticipating uncertain, systemic and distant consequences, despite cognitive limitations in reasoning beyond familiar practices and immediate effects. This paper presents AutoVision, an anticipatory design platform supporting the generation and evaluation of autonomous vehicle (AV) concepts. It combines the Study–Method–Impact (SMI) model, which structures scientific evidence on long-term socioeconomic and environmental impacts, with the Representation–Usage–Impact (RUI) model, which captures expert knowledge on social and ethical consequences. Through its Advisor and Impact Guesser modes, AutoVision links impact-oriented objectives to design directions and concepts to traceable impact pathways. We evaluated the platform with eight senior designers from an automotive group to examine its relevance and the cognitive limitations affecting responsible concept evaluation. Participants created and evaluated AV concepts, including one generated through AutoVision without knowing its origin. The AutoVision-generated concept was perceived as at least as convincing as the designer-generated alternatives. Participant judgments diverged from the platform's evidence-supported evaluations, particularly on environmental and ethical issues, while their justifications covered a narrower and less nuanced range of consequences. These exploratory findings show how anticipatory support can complement designer judgment, foster reflexivity, and help address cognitive limitations in responsible concept design without claiming to predict future impacts.

Keywords: Autonomous vehicle, Long-term impacts, Design platform, Responsible design, Cognitive limitations

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Corresponding author
Bernard Yannou
bernard.yannou@centralesupelec.fr

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1. Introduction

In a context shaped by climate change and the rapid development of artificial intelligence technologies, the responsibility of designers with regard to the future impacts of the products they develop has become a critical issue. Disruptive products – understood here as technologies capable of profoundly reshaping usage patterns, markets and social practices – raise particularly acute questions in this

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respect. Autonomous vehicles (AVs) are a salient example: while they promise benefits in terms of safety, accessibility and efficiency, they also have the potential to generate long-term socio-economic, environmental, social and ethical consequences, both positive and negative, that remain highly uncertain at early design stages.

Faced with such uncertainty, designers often rely on imagination, assumptions and cognitive shortcuts to define product concepts. Jaruzelski, Staack & Goehle (2014) note that technology-driven strategies are frequently adopted to cope with this uncertainty, leading to the development and deployment of technologies based on implicit hypotheses about future uses, since user needs and societal contexts are largely unknown at that point. Yet responsible innovation explicitly calls for anticipating potential impacts as early as possible in order to avoid undesirable consequences for individuals and society (Tatum 2004; Melles, de Vere & Misic 2011; De Saille 2015; Auger & Hanna 2019). This ambition immediately encounters the well-known Collingridge dilemma (Worthington 1982): when technologies are still flexible, their impacts are difficult to assess, whereas once consequences become observable, technological trajectories are often stabilised and difficult to change. Moreover, as argued by Chan (2018) and Parsons (2015), designers are not necessarily well positioned to characterise such long-term and systemic consequences on their own.

Within this context, responsible innovation and responsible design are best understood as normative approaches to governing socio-technical change under conditions of uncertainty, rather than as a narrow ethical add-on. Stilgoe *et al.* (2013) conceptualise responsibility through four interrelated dimensions – anticipation, reflexivity, inclusion and responsiveness – defining it as a continuous capacity to explore consequences, question assumptions, involve affected parties and adapt innovation trajectories when concerns arise. Von Schomberg (2012) situates this perspective within European traditions of Technology Assessment and foresight, emphasising the need to embed impact assessment and forward-looking inquiry into the steering of research and innovation. At the design-research level, Value Sensitive Design (Friedman, Kahn & Borning 2007) proposes a structured integration of stakeholder values through conceptual, empirical and technical investigations, while Nihlén *et al.* (Nihlen, Doorn & van de Poel 2015) argue for treating responsibility itself as a value to be designed into socio-technical systems, with explicit attention to distributed agency and accountability. Sattlegger, Van den Hoven & Bharosa (2022) further highlight that responsibility is not merely an individual virtue, but a relational and institutional property negotiated among multiple actors. Complementary contributions frame responsible design as a professional challenge, in which designers are asked to answer for consequences that are diffuse in time, mediated by infrastructures and organisations and only partially knowable at the moment of design (Tatum 2004; Melles *et al.* 2011). De Saille (2015) additionally shows that responsibility is also shaped at the policy level, through institutional frameworks that redefine what counts as legitimate innovation and which impacts become governable.

A key implication of this literature is that responsibility cannot be assumed to arise spontaneously from designers' good intentions. Ethical reasoning is subject to systematic cognitive limitations. Chugh, Bazerman & Banaji (2005) describe bounded ethicality as a source of ethical blind spots even among well-intentioned professionals, while Tenbrunsel and Messick (2004) explain ethical fading,

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whereby moral dimensions become obscured when decisions are framed in technical, organisational or economic terms. Kunda (1990) further shows how motivated reasoning leads individuals to selectively interpret information in ways that protect preferred conclusions. In design contexts, these mechanisms may result in the rationalisation, minimisation or denial of inconvenient impacts that threaten project objectives, timelines or organisational narratives. Consequently, responsible design frameworks insist on process-level safeguards – such as reflexivity, inclusion and explicit articulation of values – rather than relying solely on individual moral competence (Friedman, Kahn & Borning 2007; Stilgoe, Owen & Macnaghten 2013; Sattlegger *et al.* 2022).

These difficulties are exacerbated in the case of disruptive technologies. Early design phases are characterised by deep uncertainty regarding future contexts of use, adoption dynamics and indirect societal effects. As captured by the Collingridge dilemma (Worthington 1982), this structural asymmetry makes anticipation particularly challenging. While responsible innovation and Technology Assessment approaches elevate anticipation and responsiveness as core principles (Von Schomberg 2012; Stilgoe *et al.* 2013), they do not claim to predict impacts; rather, they aim to institutionalise earlier and broader engagement with possible consequences. Cognitive limitations (Kunda 1990; Tenbrunsel & Messick 2004; Chugh, Bazerman & Banaji 2005) further explain why designers and organisations may resist or deny medium- and long-term impacts even when confronted with evidence, especially when acknowledging such impacts implies responsibility, redesign costs or strategic delays.

Despite this need, existing design methods provide limited support for responsible design of disruptive products such as AVs. Numerous ideation methods – brainstorming techniques (Bila-Deroussy 2015), stimulation techniques (Al Maghraoui *et al.* 2019), TRIZ (Теория решения изобретательских задач, Teoriya Resheniya Izobretatelskikh Zadach; Theory of Inventive Problem Solving) (Savransky 2000), design thinking (Dorst 2011; Razzouk & Shute 2012), SWOT analysis (Ifediora, Idoko & Nzekwe 2014), Substitute, Combine, Adapt, Modify, Put to another use, Eliminate, Reverse/Rearrange (SCAMPER) (Serrat 2017) or the six thinking hats (de Bono 2017) – have demonstrated their ability to generate a large number and diversity of ideas (Hernandez, Shah & Smith 2010; Hernandez, Schmidt & Okudan 2013; Daly *et al.* 2016). However, very few allow for the direct generation or early evaluation of responsible ideas. While eco-innovation methods address environmental aspects (Tyl *et al.* 2014), ethical and social dimensions are rarely integrated from the outset. This limitation is particularly problematic for AVs, where user acceptance depends on complex cognitive and emotional factors related to usage contexts, with safety being paramount (Yoganathan & Osburg 2024). Designers may thus promote seemingly innovative concepts without being able to project their integration into users' daily lives over long periods, increasing the risk of committing to trajectories with irreversible negative consequences.

Conversely, impact assessment and technology assessment methods aim precisely at anticipating long-term impacts (Coates 1974; Arnstein 1977; Ported 1995; Becker 2001; Banta 2009; De Jesus 2009; Morgan 2012). However, these approaches are often difficult to implement for designers, require specialised expertise and typically presuppose a well-defined concept. Other approaches seek to make design processes more ethical without guaranteeing the ethicality of outcomes (d'Anjou 2011), while strategic foresight methods (Godet & Durance

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2011) and expert-based approaches may focus on limited categories of impacts (Henchey 1978). As a result, a methodological gap persists: ideation and agile methods support creativity and rapid iteration but poorly address long-term responsibility, whereas assessment methods support anticipation but intervene too late or remain inaccessible at early design stages.

This paper focuses on AVs as a paradigmatic case of a disruptive product whose long-term implications remain uncertain. An AV is defined here as a road vehicle capable of transporting passengers and operating without human intervention (State of California 2022). The scope of the study is limited to taxi, car and small shuttle vehicles operating at automation levels 4 and 5, as defined by the SAE J3016 standard (SAE International 2021), and considers both private and shared modes of use. As illustrated by Townsend (2020), AVs may generate cascading impacts across multiple time scales, from short-term effects such as job losses and market concentration to long-term transformations including urban sprawl, erosion of human agency and algorithmic governance.

To address the limitations of existing methods, the AutoVision design platform was developed by the authors for designers working on AVs. By combining elements of ideation methods, agile approaches and impact assessment, AutoVision aims to help designers anticipate long-term socio-economic, environmental, social and ethical impacts of disruptive products such as AVs. The platform has been described in detail in previous work (Lecomte *et al.* 2024, 2026). However, the present paper is the first to present AutoVision as an integrated design platform, to describe its complete operating logic and to evaluate its performance in comparison with professional designers.

AutoVision does not claim predictive certainty. Rather, it functions as an anticipatory and traceable decision-support artefact intended to make dispersed evidence and expert reasoning actionable during early concept design. In this paper, the ability to anticipate such long-term impacts and integrate them into design decision-making is considered a core component of responsible design.

The objective of this article is therefore twofold: first, to present and empirically evaluate AutoVision as a novel Design Science artefact for AV concept generation and evaluation; second, to mobilise the platform in an exploratory experimental setting designed to examine the difficulties encountered by automotive designers when attempting to take long-term impacts into account.

2. Contributions of the paper

This paper contributes to the Design Science community in four ways:

- Artefact contribution: it introduces AutoVision as a new anticipatory design platform integrating ideation support with long-term impact assessment.
- Methodological contribution: it proposes an experimental protocol comparing designer judgments with transparent evidence-supported platform evaluations.
- Empirical contribution: it shows that an AutoVision-generated AV concept can be perceived as at least as convincing as concepts generated by experienced designers.
- Theoretical contribution: it provides evidence of cognitive limitations affecting designers' ability to anticipate long-term socioeconomic, environmental, social and ethical impacts, thereby enriching research on design cognition and responsible design

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The remainder of the paper is structured as follows. Section 2 presents the principles, structure and operating modes of the AutoVision design platform, drawing on previously published work (Lecomte *et al.* 2024, 2026) and associated supplementary materials. Section 3 describes the experimental design. Section 4 presents the results. Section 5 discusses their implications for Design Science, responsible innovation and AV design.

3. AutoVision design platform

3.1. Platform structure

The AutoVision platform is built on two original models:

- the Study–Method–Impact (SMI) model, which synthesises scientific literature to anticipate quantitative long-term socio-economic and environmental impacts (Lecomte *et al.* 2026),
- and the Representation–Usage–Impact (RUI) model, which combines expert knowledge from sociology and other fields to anticipate qualitative social impacts (Lecomte *et al.* 2024). Experts are sociologists, urban planners, medical doctors, psychologists, geographers and lawyers.

A comparative summary of the models is presented in Table 1. AutoVision is a stimulation platform that allows designers to imagine concepts that are more responsible, but it is not a prescriptive tool as the time scales are obviously too high to predict impacts with certainty. The platform is based on scientific studies and expert opinions. The quality of the platform's results cannot be verified due to the long-term nature of the anticipated impacts (approximately 30 years in the future according to ERTRAC 2019).

The platform operationalises these two knowledge models – SMI and RUI – through a network of 14 interconnected databases illustrated in Figure 1. This relational architecture is not merely a data-storage solution: it preserves the traceability of the links between design characteristics, knowledge sources, validity conditions and anticipated impacts, thereby allowing designers to inspect and contest the reasoning underlying each recommendation.

Detailed database attributes are reported in Supplementary Material 5. At the platform level, their integration enables two complementary forms of reasoning: the RUI model broadens the range of socially plausible consequences considered, whereas the SMI model qualifies impact claims through published evidence and explicit validity conditions.

3.2. Epistemological assumptions

Both the RUI and the SMI models are grounded in a shared constructivist and pragmatist epistemology, explicitly designed to address the profound uncertainty that characterises the long-term impacts of disruptive technologies. At their core, both models reject predictive positivism and technological determinism. They assume that impacts are not intrinsic properties of artefacts, but emerge from situated interactions between technologies, usages, social contexts and interpretative frameworks. Consequently, knowledge about impacts is considered partial, provisional and contingent, and its value lies not in forecasting accuracy but in its capacity to support responsible action in the present.

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Table 1. Summary of the two knowledge models used by the AutoVision design platform

Model	Impact type	Knowledge source	Input characteristics	Examples of impact	Publications
SMI (Study–Method–Impact)	Socio-economic and environmental (quantitative)	Scientific studies	Validity domain (e.g. mode of use, type of infrastructure, geographical area of deployment)	Average increase in the number of kilometres travelled by 20%; Average decrease in CO_2 emissions by 5%	Lecomte *et al.* (2026)
RUI (Representation–Usage–Impact)	Social (qualitative)	Expert elicitation	Usage made possible by the AV (e.g. sleeping in the vehicle during the journey)	Increased dependence on smartphones; Decreased health status of users	Lecomte *et al.* (2024)

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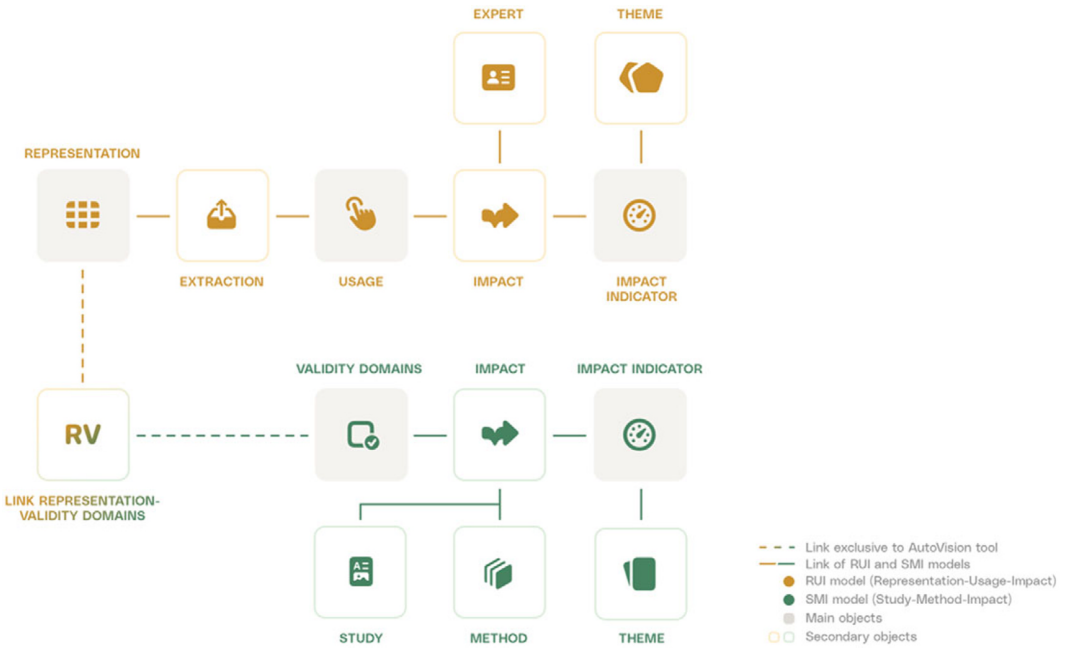


Figure 1. Objects used by AutoVision platform are spread across 14 databases.

A central common assumption is that anticipation is possible without prediction. Both models acknowledge that long-term impacts cannot be empirically verified ex ante, yet they assert that credible forms of anticipation can be constructed through structured mediation. In the RUI model, this mediation relies primarily on expert judgment in the social sciences, mobilised through representations and usage abstractions that enable projection into plausible futures. In the SMI model, anticipation is grounded in the systematic aggregation and contextualisation of existing scientific studies, making explicit their methods, assumptions and domains of validity. In both cases, uncertainty is not treated as a flaw to be eliminated, but as an intrinsic feature that must be made visible, structured and navigable.

Another strong epistemological convergence lies in their action-oriented stance toward knowledge. Both models assume that knowledge is produced for use, not for theoretical closure. They deliberately favour transparency, traceability and accessibility over causal exhaustiveness, and conceive models as epistemic mediators between science and design rather than as explanatory theories of social change. Making impacts visible is itself understood as a normative act, intended to influence design choices and responsibilities.

The two models differ mainly in the sources and nature of knowledge they mobilise. RUI privileges qualitative, interpretive and forward-looking knowledge elicited from experts, using representations as cognitive catalysts for imagination and sense-making. SMI, by contrast, relies on secondary scientific evidence and adopts a more evidence-aggregative logic, explicitly qualifying the robustness and limitations of published results. Together, they form a coherent epistemological

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ensemble: RUI explores what could happen, while SMI structures what is already known, both contributing complementary forms of anticipatory knowledge for responsible design.

These epistemological principles are operationalised through two complementary reasoning modes. The Advisor translates desired impact directions into candidate design characteristics, whereas the Impact Guesser translates proposed design characteristics into traceable impact pathways. Their combination forms an iterative anticipatory-design cycle linking normative intention, concept generation, evidence-supported evaluation and concept revision.

3.3. Typical design study with AutoVision

3.3.1. Principle

AutoVision supports two complementary design activities: generating concept directions from an impact-oriented strategy and evaluating the plausible consequences of a proposed concept. The Advisor and Impact Guesser can be used sequentially and iteratively (Figure 2). The Advisor supports divergence by opening concept directions consistent with explicit impact objectives; the Impact Guesser supports convergence and reflexivity by confronting the resulting concepts with documented impact pathways. Its output can then trigger a new generation or revision cycle.

The first *Advisor* mode is designed to prompt designers to generate responsible AV concepts expressed in terms of usages to promote, usages to avoid and contexts of use to prioritise, starting from a given company strategy. It seeks to fill a gap in existing ideation methods by enabling the direct formulation of responsible usage profiles. More specifically, the Advisor mode identifies AV characteristics – understood here as services or usages – to be encouraged or discouraged on the basis of a set of long-term consequences that designers wish to achieve or avoid (referred to as impacts), such as reducing greenhouse gas emissions or improving users' health conditions. This ability of the platform to suggest a wide range of design characteristics corresponds to what Le Masson, Hatchuel, & Weil (2016) describe as generativity.

From a design-science perspective, the Advisor operationalises responsibility as a generative design constraint. It converts abstract normative objectives – such as reducing emissions or protecting health – into actionable usages and deployment conditions that can be manipulated during concept generation. It therefore

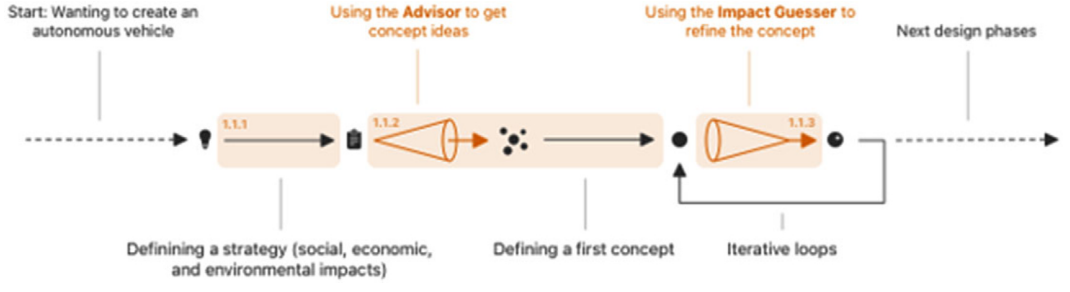


Figure 2. Example of integrating AutoVision into a design process.

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connects the impact space to the solution space at a stage when design freedom remains high.

The second Impact Guesser mode enables appraising the most plausible impacts of a given AV concept. Together, the two modes implement complementary directions of impact reasoning: an impact-to-design translation in the Advisor and a design-to-impact translation in the Impact Guesser, these two modes use a mechanism similar to case-based reasoning (Kolodner 1992).

To better understand how the platform works, the following subsections provide an example.

3.3.2. Strategy

The first step for designers using the platform is to define a strategy to follow. In AutoVision, a strategy is not merely an input list but an explicit representation of the impact priorities against which concepts will be generated and evaluated. It makes normative commitments visible and allows different stakeholders – such as manufacturers or territorial authorities – to formulate different desirable impact directions.

A strategy can include a list of impacts to be avoided or prioritised, such as reducing energy consumption or enhancing onboard safety. Supplementary Material 1 offers a comprehensive example of a strategy based on the three strategic topics of Figure 3.

3.3.3. Generation of a concept with the Advisor

Based on a *strategy*, the Advisor provides a list of *usages* to promote and avoid, as well as *validity domains* to promote or avoid (for simplicity, only the validity domains related to the mode of use, such as private or shared, will be discussed as



Figure 3. Example of three strategic topics of an automotive group from which a strategy can be defined.

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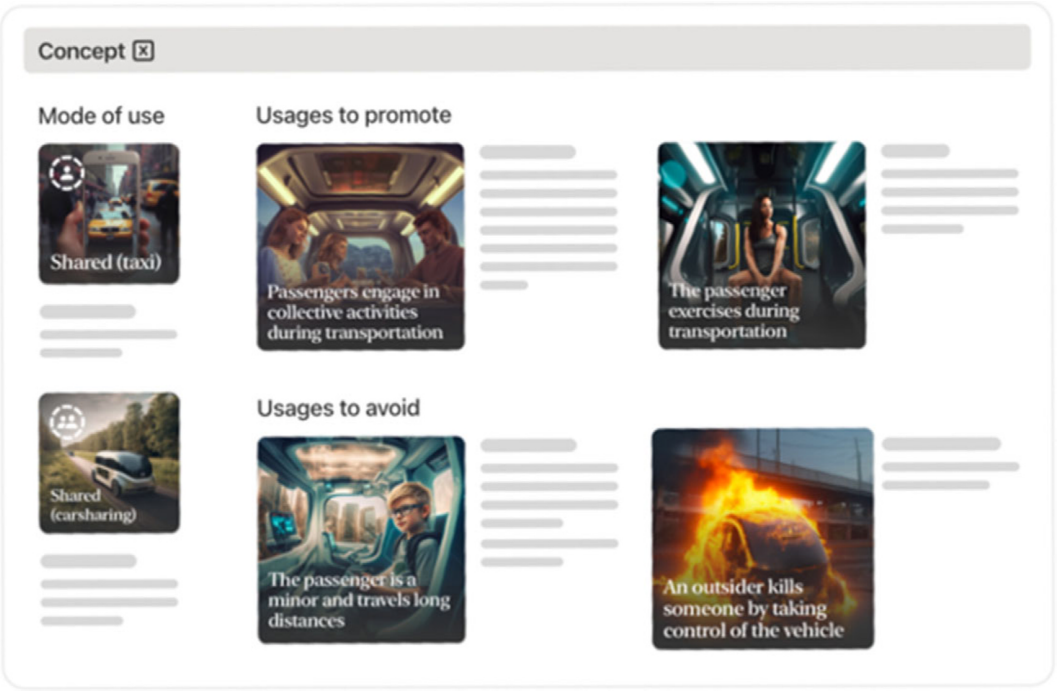


Figure 4. Extract of Concept X (full concept available in Supplementary Material 3).

examples). The Advisor has given 12 usages to promote, 16 usages to avoid, 2 modes of use to promote and 1 mode of use to avoid (Supplementary Material 2).

Designers can then use these suggestions to define a concept. In this example, six usages to promote and eight usages to avoid were selected. Concept X thus generated is visible in Supplementary Material 3, and an excerpt is shown in Figure 4.

Overall, the Advisor produced a broader set of usages and validity domains than those ultimately retained by the designers. The purpose of this output is not to prescribe a concept, but to enlarge the designers' exploration space while keeping each suggestion connected to the impact-oriented strategy.

3.3.4. Evaluation of a concept with the Impact Guesser

Based on the characteristics of an AV (e.g., those of Concept X presented earlier), the Impact Guesser can identify potential long-term social, socio-economic, and environmental impacts. These impacts are categorised into 19 themes (see Supplementary Material 3). Furthermore, the Impact Guesser can assign a score to each of these 19 themes. A positive score indicates that the impacts in this theme will be generally favourable to the strategy, while a negative score indicates that these impacts will be unfavourable. For example, a score of −75% on the "environment" theme indicates that the concept is contrary to the environmental objective of the strategy and therefore has the potential to generate more CO_2 emissions or consume more energy. The thematic score should be interpreted as a synthetic indicator of alignment between the concept's documented impact

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pathways and the selected strategy. It is neither a probability of occurrence nor a validated forecast of future outcomes.

The Impact Guesser does not predict the future consequences of a concept. It externalises impact reasoning by mapping the concept's usages and validity domains onto impact pathways documented in the SMI and RUI knowledge bases. From a design-science perspective, it acts as a reflexive evaluation device: it exposes consequences that may remain outside designers' immediate expertise and makes the supporting evidence, assumptions and expert rationales inspectable.

3.4. Advisor operating mode

The Advisor provides responsible creative suggestions to designers (Howard, Culley & Dekoninck 2011), responsible because they are based on (i) the RUI relations collected from the interrogation of sociology – and related fields – experts, for social impacts and (ii) the SMI relations collected from scientific studies for socio-economic and environmental impacts.

Users can choose trends for different impact indicators and the platform will generate lists of recommended and to-be-avoided usages and validity domains (see Figure 5 and Table 2).

Within the Advisor, RUI relations mobilise socially situated expert knowledge to connect possible usages with social consequences that designers may not spontaneously consider (Figure 6). They thereby broaden responsible concept generation beyond the designers' immediate experience and disciplinary expertise.

Complementarily, SMI relations connect validity domains – such as private ownership or deployment in Europe – with quantitative socio-economic and environmental impacts established in scientific studies (Figure 7). Within the Advisor, they qualify design recommendations through published evidence and explicit domains of validity, thereby limiting the transfer of impact claims beyond the contexts in which they were established.

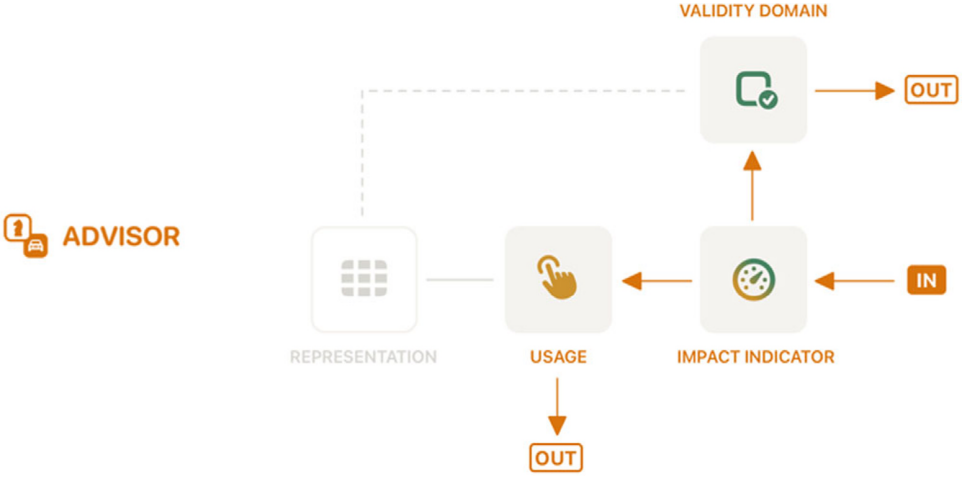


Figure 5. Advisor mode logic diagram.

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Table 2. Impact-to-design transformation performed by the Advisor mode

Stage	Operational content	Illustrative example	Design-science function
Normative framing (input)	Designers select relevant social, socio-economic and environmental impact indicators and specify the direction sought for each indicator (increase ↑ or decrease ↓). Together, these explicit impact priorities constitute the design strategy.	Stress: ↓; CO_2 emissions: ↓; Health condition: ↑	Makes the normative objectives and value priorities guiding concept generation explicit and open to discussion.
Impact-to-design reasoning	The Advisor traces the selected impact directions through RUI and SMI relations to identify usages and validity domains that are consistent – or potentially inconsistent – with the strategy.	RUI relations connect social impacts to usages; SMI relations connect socio-economic and environmental impacts to validity domains.	Translates abstract impact objectives into design-relevant knowledge while preserving the traceability of the expert judgments and scientific evidence supporting this translation.
Actionable design directions (output)	The Advisor provides usages and validity domains to promote or avoid. These recommendations constitute design directions rather than a prescribed solution and can therefore be selected, combined, challenged or rejected by designers.	To promote: passengers exercising during transport; shared mode of use.	Makes responsibility actionable during early concept generation by expanding and orienting the exploration space while preserving designers' agency.

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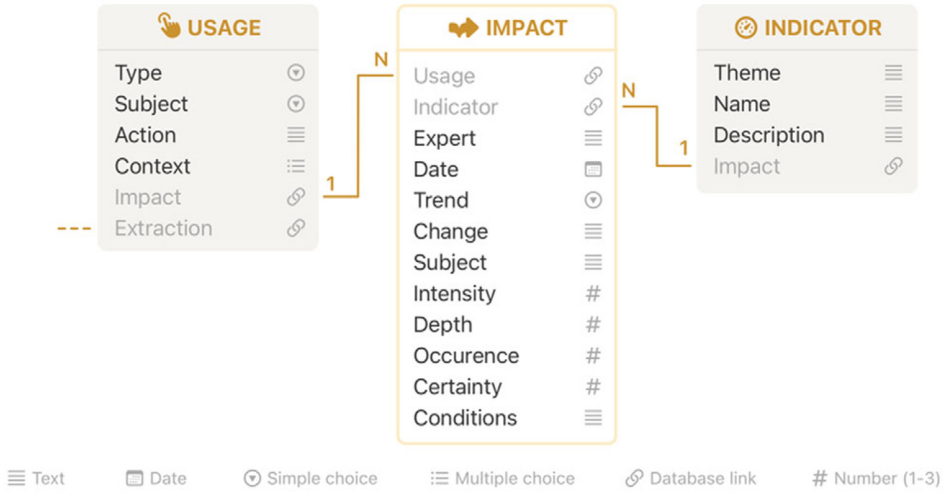


Figure 6. Some databases and links of the Representation–Usage–Impact (RUI) model.



Figure 7. Some databases and links of the Study–Method–Impact (SMI) model.

For each recommendation, three complementary indicators (see Appendix A) qualify the underlying knowledge: *majority influence* indicates direction, the *number of impacts* indicates evidence coverage and the *conflict coefficient* indicates disagreement among sources. Their joint interpretation prevents a directional recommendation from being read independently of the amount and consistency of the available knowledge.

The combination of RUI and SMI relations prevents responsible ideation from relying exclusively on either speculative expert judgement or decontextualised quantitative evidence. Detailed recommendation mechanisms are provided in Appendices A and B, while the complete SMI model is presented in Lecomte *et al.* (2026).

In addition to the lists of usages and validity domains, users can also access the links between a usage/validity domain and an impact. Traceability is treated here as

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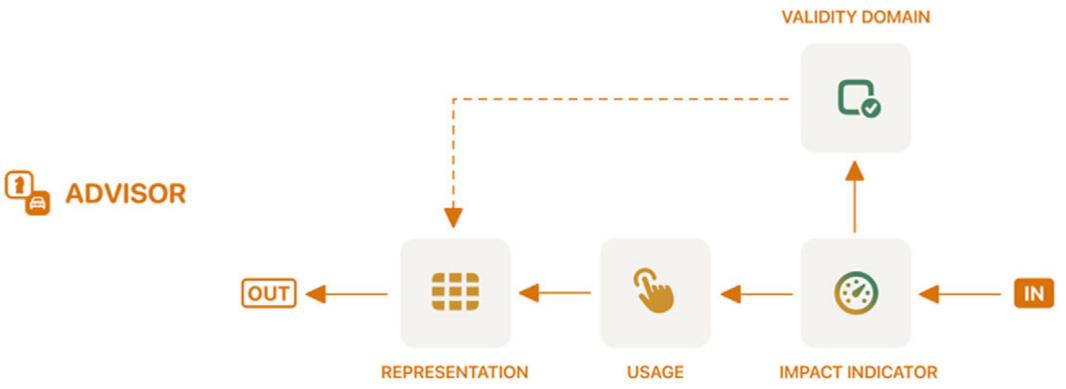


Figure 8. Alternative use of the advisor mode to display the closest representations to a strategy.

a design requirement rather than an interface convenience. For each recommendation, designers can inspect the expert rationale or scientific study supporting the relationship between a design characteristic and an impact. This enables recommendations to be questioned, contextualised or rejected rather than accepted as opaque prescriptions.

Another capability of the Advisor is to display the relevant concepts that closely align with the user's chosen strategy. For instance, if the user selects a preference for a vehicle with low energy consumption, the Advisor may suggest an existing concept of an ultra-light AV (Figure 8). Retrieving related concepts can support analogical reasoning by exposing designers to precedents consistent with the selected strategy. However, because examples may also induce fixation (Linsey *et al.* 2010; Moreno *et al.* 2016), these representations should be treated as stimuli to be challenged and recombined rather than as preferred solutions.

4. Experiment

4.1. Design of experiment

As previously indicated, the AutoVision platform was developed to support designers in anticipating the long-term socio-economic, environmental, social and ethical impacts of disruptive products such as AVs. We conceptualise this capacity to foresee and integrate long-term impacts into design decisions as *responsible design.*

The objective of this article is to mobilise the AutoVision platform to construct an experimental and methodological framework capable of revealing the challenges encountered by automotive designers when attempting to account for long-term impacts in the context of responsible AV design. More specifically, the study aims (1) to assess the extent to which designers may exhibit insufficiently responsible decision-making when developing AV concepts and (2) to characterise their cognitive limitations, forms of resistance or attitudes of denial regarding long-term considerations.

Because this framework is grounded in the AutoVision platform, the first part of the paper was devoted to outlining its principles, structure and operational mechanisms. The second part – constituting the core contribution – focuses on the

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design of the empirical study intended to uncover the phenomena described above. The experiment was constructed to address three research questions by engaging a group of carefully selected designers tasked with making decisions about long-term AV concepts within an automotive company. The three hypotheses are as follows:

H1. *A concept generated through the AutoVision Advisor mode is perceived by designers as at least as convincing as a concept they would have developed themselves.* Here, 'convincing' refers to the perceived alignment between a concept and an impact-oriented strategy, as judged by other designers. This hypothesis examines whether the Advisor can generate a concept that professionals perceive as aligned with this strategy; it does not test the correctness of the anticipated impacts.

H2. *Designers' assessments of the long-term responsibility of autonomous vehicle concepts will diverge from AutoVision's evidence-supported evaluations, particularly for indirect, systemic, and long-term impacts.*

H3. *AutoVision's traceable expert rationales will cover a broader and more nuanced range of consequences than designers' justifications.*

To address the first hypothesis, it is necessary to compare how persuasive a concept generated using the Advisor is for designers in comparison to concepts envisioned by these designers. To examine the second hypothesis, participant evaluations are compared with AutoVision's evidence-supported evaluations, not as a test of ground-truth accuracy but as an analysis of divergence between two forms of judgment. To test the third hypothesis, it is necessary to qualitatively compare the justifications of the participants with the justifications of experts (Impact Guesser). The experiment was therefore built around these three prerequisites, as shown in Figure 9.

The first 20 minutes are spent explaining the context and details to the participants (see Supplementary Material 7).

The experiment involved eight senior automotive designers from a major international automotive group. Although this number may appear limited, these participants represent the organisation's most experienced and dedicated experts in the long-term design of AV concepts. It would not have been possible to recruit many more. They are divided into three groups of two to three people, and each group must come up with a preliminary concept of AVs (they get 30 minutes). This concept should include a list of desired and undesired usages, as well as one or more modes of use (you can see an example in Figure 4). It must align with the three strategic topics presented in Section 3.3.2, which are related to the automotive company's public communication where the participants are employed. A list of 30 usages and 3 modes of use is provided to each group. The groups are instructed to choose a minimum of five usages to promote and five usages to avoid. They are also instructed to select one or more modes of use among "private," "shared: ridesharing" and "shared: carsharing." For each selection, they are encouraged to provide at least one justification. The concepts generated are labelled as A, B and C.

To have a point of comparison, a fourth concept – called Concept X – is generated by experimenters using the Advisor. This is the concept presented in Section 3.3.3.

The four concepts are evaluated by participants (they also get 30 minutes). Each group is asked to evaluate the (anonymised) concepts of the other two groups, as

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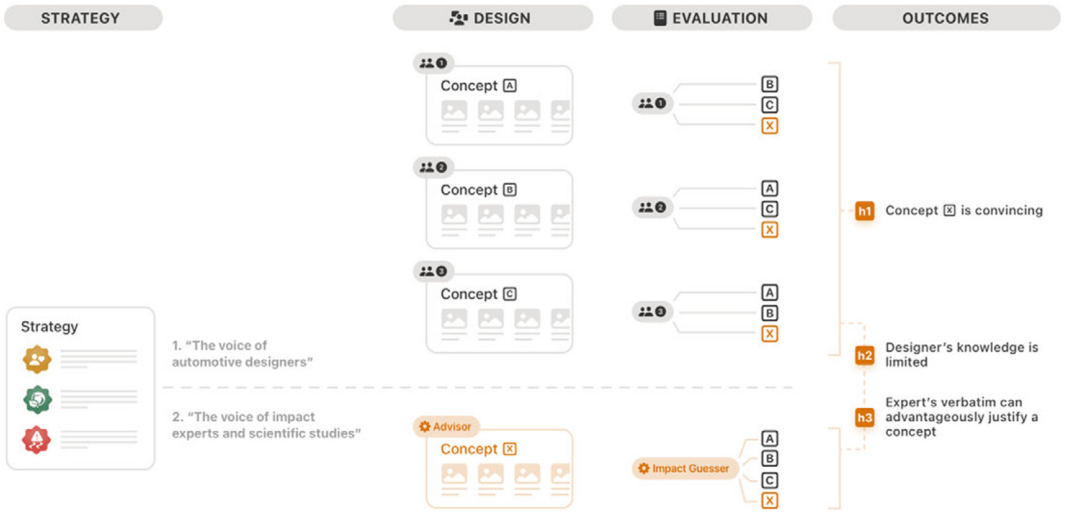


Figure 9. The experiment's design to test the three hypotheses.

well as Concept X generated using the Advisor mode. Participants are not informed that Concept X was not created by human designers. The evaluation is conducted for each strategic topic (ethical responsibility, environmental responsibility and security) and is done using an online evaluation form. Written justifications are also required from participants (at least 100 characters) for their ratings.

The four concepts are also evaluated by the Impact Guesser to provide a specific score for each strategic topic (on ethical responsibility, environmental responsibility and security). The Impact Guesser also gives written justifications from experts.

So, as shown in Figure 9, the experiment stages the creation of concepts and their justified evaluation based on (1) "the voice of automotive designers" (the participants) and (2) "the voice of impact experts and scientific studies" (the AutoVision platform).

After a brief intermission, the results are presented to the participants in the form of a ranking of concepts A, B, C and X according to the participants. Concept X is also disclosed to the participants. To provide a glimpse of the AutoVision platform to participants, experimenters then suggest taking the concept with the highest overall score (among A, B and C) and inputting it into the Impact Guesser to assess its potential impacts.

4.2. Criteria

To test the hypothesis (H1), the scores given by the participants for the four concepts A, B, C and X can be used to determine whether the concept generated by the Advisor (X) is at least as convincing or not.

To examine H2, the evaluations made by participants are compared with the evidence-supported evaluations produced by the Impact Guesser. The analysis concerns the direction and magnitude of divergences between these two forms of

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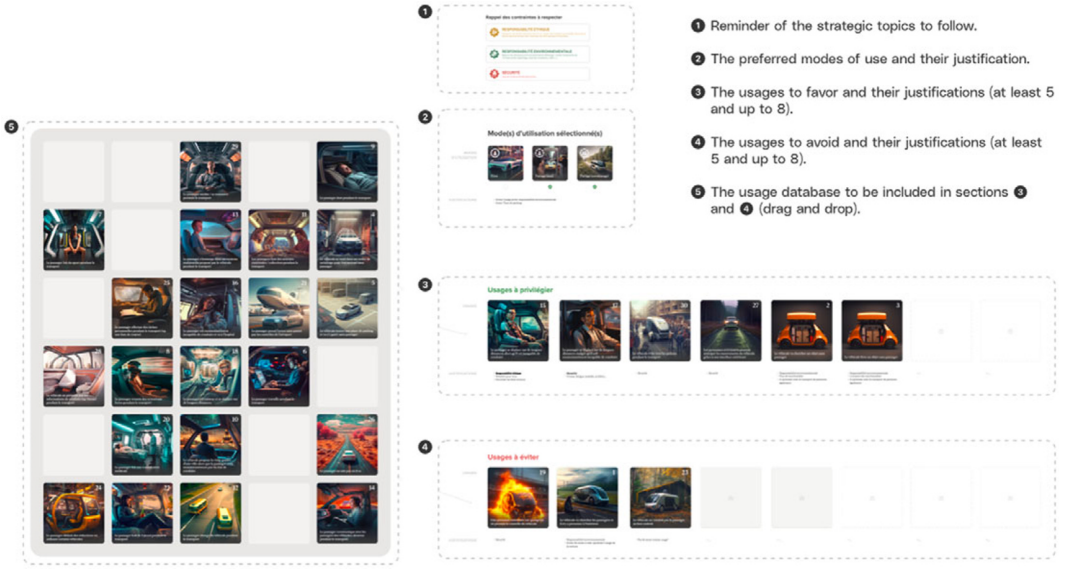


Figure 10. The dashboard provided to the groups to imagine their concept based on an existing database of usages.

judgment, rather than the accuracy of either evaluation against an empirically verified future outcome.

The Impact Guesser is used to provide a score on each of the 19 themes of the platform. The scoring is only done for the usages to be promoted (Figure 10, area 3). To compare with participant's evaluations, the themes need to be converted into scores for each of the three strategic topics. To do this, each theme was assigned to a topic (Table 3).

The calculation of scores for each strategic topic is done by calculating the average score for each theme corresponding to the topic, weighted by the number of impacts considered for each theme.

To examine H3, participant justifications are qualitatively compared with the expert rationales retrieved by the Impact Guesser, focusing on their breadth, level of elaboration and capacity to articulate contrasting consequences.

Table 3. Matching between impact themes and the three strategic topics

Strategic topic of the experiment	Impact themes of the AutoVision design platform
Ethical responsibility	Education; Employment; Family; Genre; Health and welfare; Human rights; Identity and cultural heritage; Stratification
Environmental responsibility	Energy; Environment
Security	Conflict and crime
None	Networks and communication; Population change; Distance; Speed; Time; Traffic; Transport share; Parking

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4.3. Details of experimentation supports

4.3.1. Concept imagination dashboard

Participants used a standardised Mural dashboard to select modes of use and five to eight usages to promote or avoid, together with written justifications (Figure 10).

Printed cards ensured that all group members could examine the available usages independently of the shared computer (Figure 11).

The same set of 30 usages was used by both the participants and the Advisor, ensuring that the human- and platform-generated concepts were based on identical design material.

4.3.2. Evaluation form

An online form then collected ratings from 0 to 6 and written rationales for the three strategic topics (Figure 12).

Complete instructions and experimental materials are provided in Supplementary Material 7; examples of completed dashboards are available in Supplementary Material 3.

4.4. Participants

The experiment took place in a single session with eight skilled designers inside an automotive company. These individuals had decision-making authority and were responsible for actual projects within the company, thus playing a strategic role.

To form three groups, the eight participants were asked to mingle. The goal was to encourage diverse perspectives and prevent biases associated with a specific population. Additionally, this provided them with the chance to meet new people

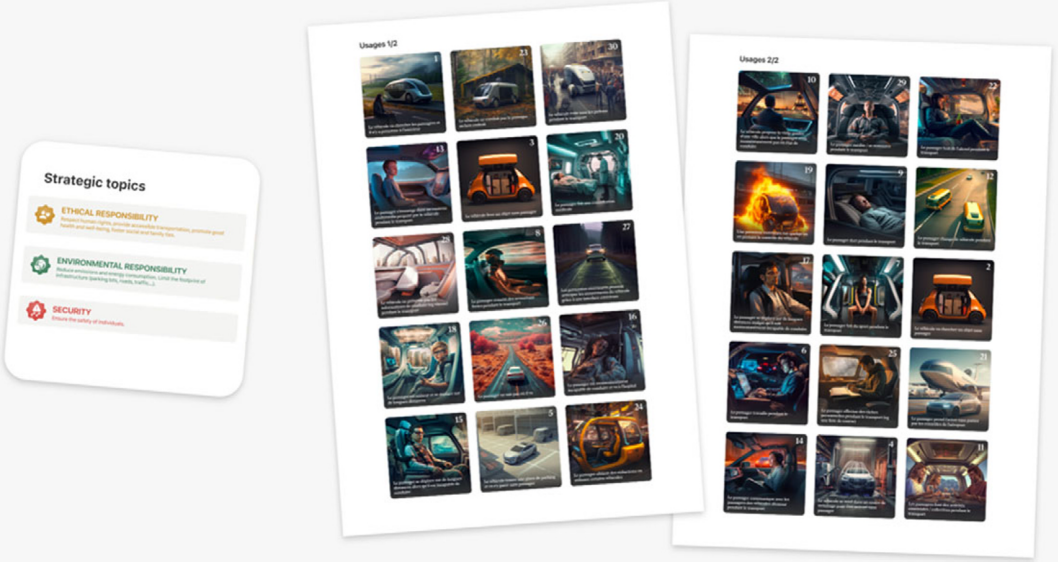


Figure 11. Sheets distributed to participants to remember the strategic topics and to go through the 30 usages without having to look at the computer (see Supplementary Material 7).

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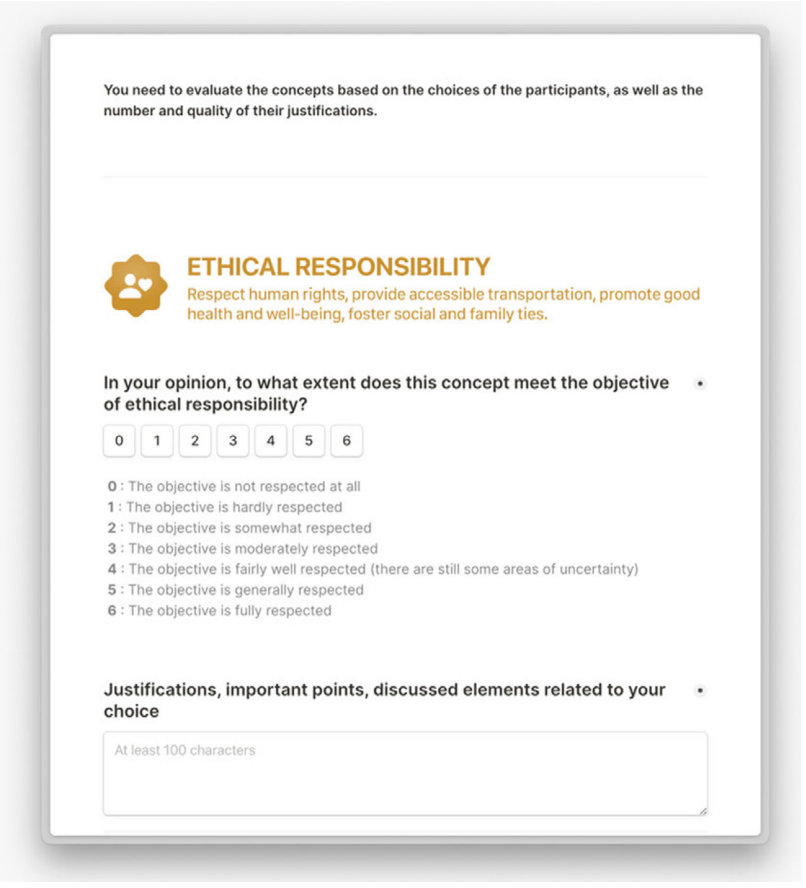


Figure 12. Excerpt from the evaluation questionnaire related to the strategic topic of ethical responsibility (translated into English). For each AV concept, two complementary ratings are also collected: environmental responsibility and security.

within the company. Groups 1 and 2 had three participants each, and Group 3 had two participants.

4.5. Evaluation distribution

During the evaluation phase, the different concepts were randomly assigned to the groups. Table 4 provides a summary of this distribution. The participants who had a laptop received the links to the (anonymised) concepts that needed to be evaluated via email.

5. Results

5.1. Participant evaluations

Figure 13 presents the evaluation results for the three strategic topics, as well as an overall average. Concepts A, B, and C were rated by two groups, while Concept X

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Table 4. Distribution of the four concepts among the groups for evaluation. The numbers in parentheses correspond to the identifier that participants saw

Group 1 – Concept A	C (11)	X (21)	B (31)
Group 2 – Concept B	X (12)	C (22)	A (32)
Group 3 – Concept C	B (13)	A (23)	X (33)

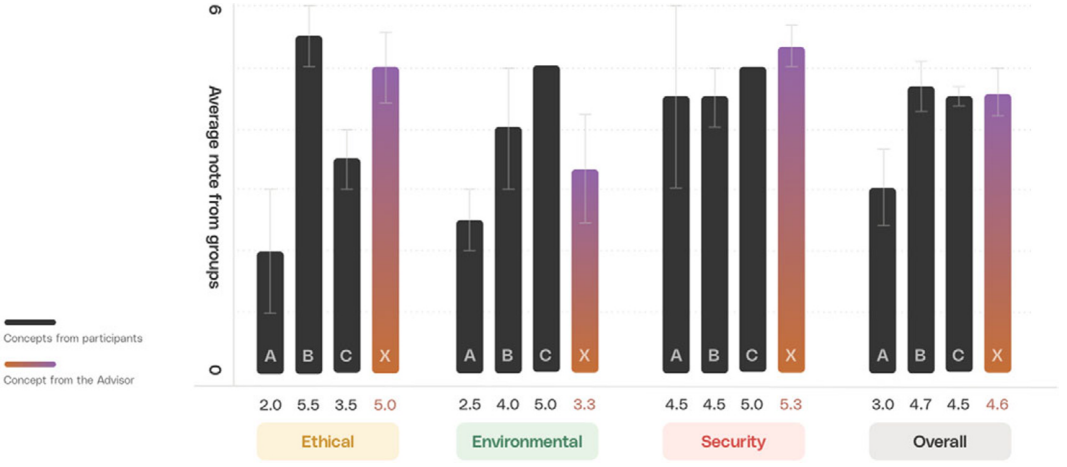


Figure 13. Human evaluation of the four AV concepts. Means and standard errors of ratings on the 0–6 scale are shown for descriptive purposes. Differences should be interpreted as indicative patterns rather than statistically significant effects.

was rated by all three groups. The raw results and detailed calculations can be found in the Supplementary Material 8. The results presented in this section are exploratory and descriptive in nature. Given the small sample size ($n = 8$), the non-random selection of participants and the partially overlapping evaluation structure (each concept being assessed by different groups), inferential statistical tests were not applied. Under these conditions, statistical significance testing would violate standard assumptions of independence and statistical power and could lead to misleading conclusions. Consequently, the results are interpreted as indicative patterns intended to support qualitative and comparative analysis rather than statistical generalisation.

When it comes to ethical responsibility, Concepts B (with an average rating of 5.5) and X (with an average rating of 5.0) outperformed Concepts A (rating of 2.0) and C (rating of 3.5). One group stated that Concept B took into account both individual needs and collective modes of use. The groups evaluating Concept X praised its emphasis on health, well-being and family connections. The groups evaluating Concept A stated that only one usage was related to ethics, without any argumentation. One of the groups evaluating Concept C explained that there was no consideration for accessibility, health/well-being or human rights.

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Regarding environmental responsibility, Concept C dominates the others with an average score of 5.0. One of the groups stated for Concept C that the strategic topic had been respected with an emphasis on optimisation. Concept B ranked second with an average score of 4.0. One of the groups explained that environmental aspects seemed less present in the justifications for usages compared to Concept C. Concept X obtained a score of 3.3. The three groups that evaluated it do not agree with each other. One of the groups deemed the proposal as good as the others (rating of 5). Another group explained that there were few arguments regarding the environment (rating of 3). The last group criticised the choice of a usage that allows for sports, which could lead to additional weight (rating of 2). Finally, Concept A obtained an average score of 2.5. The groups justified their ratings by saying that there were only two or three usages related to the environment, without elaborate justifications.

Regarding security, the four concepts have close and fairly high scores. Concept X is the highest with a score of 5.3. The groups that evaluated this concept found that it proposed many arguments about security. One group considered the topic respected but expressed one concern about the absence of first aid options. Concept C obtained a score of 5.0. One of the groups explained that safety was emphasised for both vehicle and external users. Concepts B and A both scored 4.5. For Concept A, one of the groups explained that security was fairly well represented in the usages chosen, but the arguments were less developed than for ethics. Finally, for Concept A, one of the groups stated that the safety aspect was overwhelmingly dominant in the formulated choices (rating of 6), but another group nuanced it by saying that there were too few justifications (rating of 3).

In terms of overall averages, Concept A (score of 3.0) is overshadowed by the other three, which are all very close with each other: B with 4.7, X with 4.6 and C with 4.5. The standard error depicted in Figure 13 suggests that the top three concepts cannot be definitively ranked. However, it is evident that concept A is falling behind the others, primarily due to its lower scores on ethical and environmental topics.

5.2. Impact Guesser evaluations

Figure 14 presents the ratings delivered by the Impact Guesser for the three strategic topics as well as an overall average. The raw results and detailed calculations can be found in the Supplementary Material 8.

Concept X received the highest overall Impact Guesser score. Because this concept had been generated using the Advisor, this pattern was expected; however, it should be interpreted descriptively and not as evidence of statistically significant superiority.

Regarding ethics, two concepts received a positive score (C and X). Concept X is the highest with a score of +49%, mainly due to strong scores on the themes of health and welfare and employment. Next, Concept C achieved +41%, thanks to a very good score on employment. Concepts A and B received scores of −3% and − 8% respectively, suggesting that they may have a negative impact on ethical responsibility in the future. The low score of Concept A is primarily because of a very poor score on employment, but it is balanced by positive scores on human rights and identity and cultural heritage. The low score of Concept B is attributed to a poor score on health and welfare and a score close to zero for all other themes.

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Figure 14. Impact Guesser (AutoVision) evaluation of the four AV concepts. The score is given on a scale from −100% to 100%.

Regarding the environmental topic, all four concepts received high scores. Concepts A and X scored +56%, while Concepts B and C scored +33%. The two themes of the environmental topic were energy and environment, and their scores were consistently similar across the four concepts.

Regarding security, Concept X was the only concept with a positive alignment score (+33%). The other concepts showed negative alignment scores for this strategic objective: −1% for Concept A, −5% for Concept C and − 15% for Concept B. The topic of security was exclusively represented by the theme of conflict and crime.

Overall, Concept X received the highest Impact Guesser score (+46%), followed by Concepts C (+23%), A (+18%) and B (+3%). Concept B was mainly impacted by its low scores in security and ethics.

5.3. Qualitative comparison of participants' justifications and expert opinions

To further the analysis, the justifications provided by the participants to justify their concepts were qualitatively compared with the expert opinions from the AutoVision's Impact Guesser.

The impacts to avoid were not considered, as the Impact Guesser was not used on them. It should also be noted that no expert opinion concerns the environmental strategic topic, as it deals with quantitative impacts drawn from the literature (SMI model, see Lecomte *et al.* (2024)).

On average, participants justified their choices with 250 words, whereas expert opinions from Impact Guesser provided an average of 1,200 words per concept – nearly five times as many words. To improve readability and reduce redundancy, the expert opinions have been synthesised to approximately 600 words per concept.

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Concepts	Participants of the experiment	Experts' opinions from AutoVision's Impact Guesser
A	Ethical Responsibility Mobility for All Promote Social Connections Safety Less drunkenness, Fatigue, Illness, Accidents... Flow of goods, goods delivery to be optimized with passenger transportation as well Environmental responsibility	The profession of delivery driver is at risk of disappearing due to the automation of vehicles and the ability to program them to transport objects. This automation will likely reduce employment in the delivery sector, especially for short distances where individuals can use their own cars for deliveries. Improves conditions for elderly and disabled individuals to exercise their right to mobility and drive. Robot taxis provide individuals with disabilities, specifically those who are wheelchair-bound, the ability to travel long distances without needing external assistance. The possibility of long-distance travel by a person unable to drive could reduce cases of driving under the influence of drugs of alcool and benefit the food/drink service industry by allowing visits to distant drinking establishments not easily accessible by public transportation. Possibility to make a long journey directly from home to the desired destination, without the need for intermediate trips or transfers. It allows for carrying more luggage, and adds flexibility in choosing travel days and times, and the option to travel alone or with chosen companions. Less active transportation. Improving a vehicle's ability to avoid pedestrians can significantly reduce accidents and involuntary manslaughter cases involving pedestrians. This would help decrease the frequency of conflicts and offenses, addressing civil disputes and enforcing laws related to traffic accidents with pedestrians. A new mode of action involves blocking the flow of vehicles, either through structured protests with demands or simply for the enjoyment of disrupting traffic. The use of long-distance travel by a person incapable of driving could help reduce accidents caused by driving under the influence of drugs or alcool. It would provide an alternative to "drinking or driving", allowing individuals to visit distant drinking establishments not easily accessible by public transportation. This could have a positive impact on the food/drink service industry. It would also be possible to spend more time in places, as being too tired to drive for a long time would no longer be a hindrance. Object delivery using AVs may lead to an increase in attempted package theft and facilitate the trafficking of prohibited objects or substances, bypassing inspection by delivery services. Anticipating vehicle movements could be a factor in reducing conflicts in traffic.
B	Private: optimization of travel time for other tasks, well-being, social connections, safety to reduce accidents (sleep, parking, reduced mental load, less monotony when traveling alone) Shared: strengthened social or family connections, ecology (sharing a single vehicle), limited impact on infrastructure, safety as there is no driver distracted by other passengers Well-being, relaxation, social and family connections, passenger freedom, saved time, transport time = work time, increased productivity, accessibility, inclusion. Narrower parking spaces, no vehicles between two spaces, no empty spaces, no double parking... Parking = cars maneuvering, often reversing in dim light.	Reserved parking spaces for disabled individuals may need to be reevaluated with the rise of autonomous vehicles (AVs). While disabled individuals may still require dedicated drop-off locations, AVs should not unnecessarily occupy the reserved space. Some disabled individuals may choose to forgo AVs in order to retain the convenience of a reserved parking space near the entrance. There is no longer a need for a driver's license to travel in a personal vehicle. The possibility of making a long journey directly from home to the desired destination, carrying more luggage, choosing days/times, and traveling alone or with other passengers provides more options for long-distance travel, especially for those who cannot drive. It also reduces stress on holiday/weekend road trips. Motion sickness can occur when individuals lose control or focus on a vehicle's movement. This explains the preference for forward-facing seats on trains or buses. The limited curvature, linearity, and gradual accelerations of trains allow for alternative activities. In autonomous cars with lounge-like seating, motion sickness is likely, suggesting the need for motion sickness bag dispensers. The disappearance of boundaries between private and professional spheres can lead to flexibility but also burnout. Additionally, it can improve intrafamily relationships. In the world of work, schedules are a crucial and contentious issue. Those in positions of power can demand specific schedules or resist them. External constraints, such as children's schedules, the need for sleep and meals, and traffic congestion, can impact work schedules and pose risks. In the transport sector, the question arises about how sleeping during a journey will be considered for workers. Will they be compensated as if on standby or will their work be limited to administrative tasks and unloading? If the latter, how much time in the vehicle is required for a full-time schedule? Sleeping during a journey can have a positive impact on health, but it may also result in sacrificing sleep hours and lower sleep quality. Sleeping in a car or public space without surveillance can expose one to risks such as theft or assault. On a night train, restful sleep can save on accommodation and allow for longer commutes. However, sleeping in a moving autonomous car lacks security and stability. The possibility of accessing jobs safely outside of public transportation operating hours, or in rural areas without the need to own a personal vehicle. Autonomous vehicles can provide a unique and potentially social experience for groups of 2 to 5 people. While the cost may be a factor, there are various social uses such as cocktails, board games, or watching sports events. However, there is a concern about illegal activities, which can be deterred through cabin filming. This type of use is currently rare, but autonomous vehicles have the potential to popularize it in the future. Currently, in traffic, all vehicles are occupied. Those that are not occupied are stationary. Stationary vehicles can be targets of accidents, incidents, vandalism, or conflicts caused by surrounding vehicles. The presence of empty and moving vehicles can significantly impact the outcome of these incidents and traffic offenses. When a vehicle experiences a breakdown or accident, the question of how to manage the situation arises. With autonomous vehicles, the response time of a human to intervene and the identity of these humans become important. This raises concerns about vehicle owner intervention or reliance on private or state services. There is a risk of increased demand for police services, potentially hindering their ability to address other urgent tasks, especially if there are no passengers in the vehicles involved. The concept of a "reserved" parking space for autonomous vehicles (AVs) raises questions and potential conflicts. In regular parking lots, issues include determining priority between AVs and conventional vehicles, defining available spaces, and resolving conflicts in the absence of the vehicle owner. In dedicated AV parking lots, concerns involve verifying hazardous materials and preventing system hacking to steal AVs. Sending cars to park further away could reduce illegal parking and accidents involving pedestrians. It would also help reduce civil disputes and offenses related to traffic accidents. However, there may be concerns about potential new types of delinquency, such as thefts from moving vehicles or acts of vandalism. Reducing the number of accidents involving pedestrians and involuntary manslaughter cases would have clear benefits in terms of reducing conflicts, civil disputes over compensation, and enforcement of offenses. This would help in reducing conflicts and offenses related to vulnerable road users, particularly pedestrians. Sleeping alone or with others in a car allows for the convenience of a mobile hotel, but it also presents safety concerns such as theft, assault, and rape. However, it can be a cost-saving option for overnight travel and provide the freedom to live far from one's workplace. Additionally, intimate activities can take place in this confined and mobile living space. However, sleeping in an autonomous car lacks the security of a hotel and is akin to camping in a city. A new mode of action is possible: blocking the flow of vehicles for various purposes, including structured actions like demonstrations with demands or simply for the enjoyment of disrupting traffic.
C	To limit environmental impacts, shared transportation like carpooling offers the most efficient way to use automated road transportation: one vehicle can transport multiple people compared to 100% private mode and privatized taxi mode over a period of time. It allows fo cost optimization, and therefore affordable prices for end users. The advantage of shared transportation is the possibility of social and collective activities (one of the strengths of carpooling solutions today). It allows for the deployment of autonomous shuttle services on any road, including city centers and pedestrian zones. Reduction of the operational cost of autonomous shuttle services. Optimization of the route/tour, based on different routes requested by users (e.g. shared taxis in NYC). Exterior lightning facilitates the integration of autonomous shuttles into the surrounding traffic flow, not necessarily autonomous (safety benefit).	Cleaning centers can be unpleasant and unsafe due to their locations. The products used are not environmentally friendly, which may have health impacts. By freeing up time spent at cleaning centers, users can engage in more fulfilling activities for their well-being. Some individuals only experience car sickness when they are not focused on the movement of the vehicle, explaining the preference for forward-facing seats on trains or buses. The limited curvature and linear motion of trains allow for alternative activities. In conclusion, if the front seats of a self-driving car were turned around to create a living room-like setting, there is a high chance of inducing sickness, suggesting the need for vomit bag dispensers. There is a possibility to access jobs safely outside of public transportation hours or in rural areas without the need to own a vehicle. The vehicle can offer a unique and versatile space for social gatherings, such as aperitifs or game nights. However, concerns about cost, illegal activities, and loss of privacy need to be addressed. While this type of use currently exists in limited forms, self-driving vehicles have the potential to make it more accessible in the future. Additional benefits include reduced stress on trips, improved family bonding, not needing a driver's license for personal car travel, and time saved for the user. Reducing the number of accidents involving pedestrians and involuntary manslaughter is beneficial in terms of reducing conflicts, offenses, and legal consequences. This includes civil conflicts in compensation and the prosecution of offenses related to traffic accidents involving pedestrians. Accidents involving vulnerable road users, particularly pedestrians, are frequent. Reducing these incidents would have benefits in terms of conflicts, compensation, and prosecution of offenses related to traffic accidents involving pedestrians. Currently, in traffic, all vehicles are occupied. Those that are not occupied are stationary. Stationary vehicles can be targets of accidents, incidents, vandalism, or conflicts caused by surrounding vehicles. The presence of empty and moving vehicles can significantly impact the outcome of these incidents and traffic offenses. In the case of incidents or accidents involving autonomous vehicles, questions arise regarding the response time for human intervention and the identity of these humans. The need for police services may increase, potentially impacting their ability to handle other urgent tasks. The situation becomes more delicate if none of the vehicles involved have passengers who can take charge of the situation. From a security standpoint, potential concerns include thefts from vehicles in traffic and deliberate damage. A new mode of action involves blocking the flow of vehicles, which can be used for organized protests with demands or simply for the enjoyment of disrupting traffic. Anticipating the movements of vehicles could be a factor in reducing conflicts in traffic.

Common elements Similar elements Disagreeing elements No common points

Figure 15. Qualitative comparison between the justifications provided by the groups for their choices, and the summary of expert opinions provided by the Impact Guesser (number of words reduced by two times). This table can also be found in Supplementary Material 8.

The comparison is shown in Figure 15. Supplementary Material 8 provides more details on this comparison and allows for a more suitable reading experience.

The first thing that stands out is the difference in the accuracy of rationale provided by the participants and the experts. The participants generally did not seek to explain the rationale behind their justifications. Concept A is particularly striking in this regard, as some of the justifications are limited to a few words like "safety" or "environmental responsibility." This was obviously too broad to find any points of comparison with the experts, as highlighted in yellow.

Another notable aspect is that many of the topics discussed by the experts are not reflected in the justifications provided by the participants. In fact, some elements used to justify a concept are even contradicted by the experts. For example, Concept B justifies the usage of "working in the vehicle" by claiming that it allows for more working time. The experts acknowledge that working in the vehicle can provide flexibility, but it also carries the risk of burnout (highlighted in red). This last example illustrates another point: the lack of nuance in the participants' justifications. Overall, they did not engage in deep reflection to anticipate the consequences that their choices could have. Instead, they settled for immediate and obvious justifications that are always positive, resulting in depicting rather idealised concepts of AVs.

5.4. Observations during the experiment

The concept imagination phase lasted 50 minutes (instead of 30), and the evaluation phase lasted 46 minutes (instead of 30).

Some participants were unsure about the main goal of the experiment. It appears that they did not grasp the importance for their company to anticipate long-term effects. Some expressed their mindset of "let's just stick to our usual business practices." Additionally, some participants found the evaluation intellectually challenging – especially the need to provide a minimum of 100 characters to explain their evaluations.

All groups identified the concept generated using the Advisor before the end of the experiment. One group noticed that Concept X was more detailed compared to the others. This is supported by the number of words used, which was significantly higher than for the other concepts (731 words compared to 244 for the participant's concept with the most words). Another group thought that the explanations for the concept resembled those that could have been generated by a Large Language Model like *ChatGPT*. Confident in their convictions, and despite our denials, they described the explanations as "generic" and sometimes even absurd, even though they were exact transcriptions of the experts' comments used to feed into the AutoVision databases, with no possible LLM hallucination. At this point, no participant was aware that the data used to generate Concept X came from experts or scientific studies.

At the end of the experiment, the Impact Guesser was used in a plenary session on Concept B (the concept that received the highest score from participants). It was shown that by removing the initially chosen private mode of use, the environmental score could be significantly increased. Participants had two reactions: some questioned themselves and admitted their lack of knowledge, while others questioned the platform's ability to provide accurate information through the case-based reasoning-like mechanism – which was surprising for them.

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5.5. Interpretation of the results

We attempted to draw a more comprehensive comparison between the evaluations provided by the participants and those by AutoVision (Impact Guesser). We have therefore overlaid the two evaluations in Figure 16. Overall, the results show that:

- Concept X is among the highest-rated concepts in the participant evaluations and receives the highest overall Impact Guesser score.
- Concept B receives the highest participant mean but the lowest overall Impact Guesser score.
- Concept A receives the lowest participant mean but a higher overall Impact Guesser score than concept B.
- The two evaluation profiles diverge particularly on ethical, environmental and security-related dimensions.

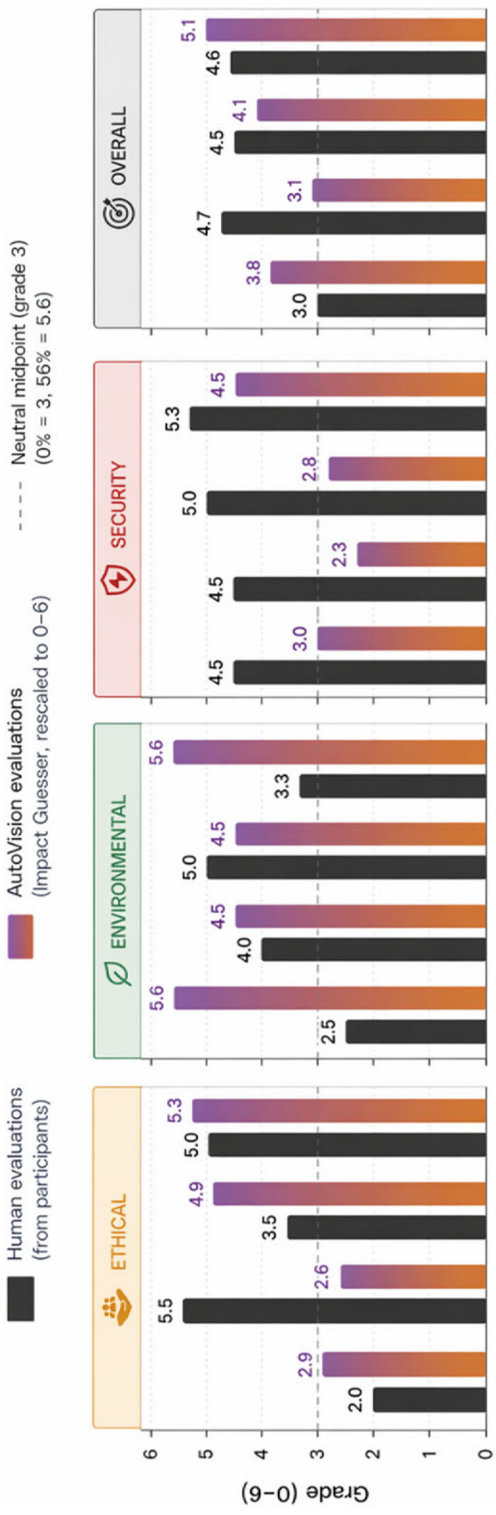
The descriptive participant ratings indicate that the Advisor-generated Concept X was perceived as similarly convincing to the highest-rated designer-generated concepts. This pattern provides exploratory support for H1; it does not establish statistical equivalence or general superiority.

The low score given to Concept A can be explained by the fact that its justifications were not as developed as those of the other concepts, as highlighted by Groups 2 and 3 who evaluated this concept. Surprisingly, the Impact Guesser prefers Concept A over Concept B on all three criteria. It is also noteworthy that the participants gave the lowest score on the environmental topic, while the Impact Guesser gave the highest score (tied with concept X). This suggests that a concept following a given strategy will not be perceived as such if the justifications are not convincing enough. This discrepancy suggests that participants did not consistently mobilise external evidence when evaluating ethical and environmental dimensions. For example, none consulted available evidence on the environmental implications of private versus shared modes of use during the exercise. Going further, Concepts B and C also received contradictory scores. On average, participants considered Concept B to be the one that best respects the strategic topics. However, it received the worst score from the Impact Guesser. For example, participants gave this concept a high environmental score even though it promotes a private mode of use, which studies have shown to contribute to climate change. These divergences support H2 by showing that participant judgments differed from AutoVision's evidence-supported evaluations, particularly for environmental and ethical dimensions. They do not establish that the platform is correct or that the designers are inaccurate; rather, they indicate the value of making alternative impact pathways and their supporting evidence explicit before concept selection.

Participant justifications were shorter and covered fewer consequences than the expert rationales retrieved by the Impact Guesser. They also focused more frequently on immediate and positive consequences, whereas the expert rationales articulated a broader range of potential benefits and drawbacks. This pattern supports H3 in terms of breadth and nuance; it does not establish that the expert rationales are necessarily more accurate.

During the debrief session, participants were taught how to use the Impact Guesser to improve Concept B. However, some of them did not recognise their lack of knowledge and instead questioned the platform's ability to question their design choices. This suggests a potential obstacle to the platform, regarding the trust that

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Numeric values (0–6)	Ethical				Environmental				Security				Overall			
	A	B	C	X	A	B	C	X	A	B	C	X	A	B	C	X
Human evaluations (from participants)	2.0	5.5	3.5	5.0	2.5	4.0	5.0	3.3	4.5	4.5	5.0	5.3	3.0	4.7	4.5	4.6
AutoVision evaluations (rescaled to 0–6)	2.9	2.6	4.9	5.3	5.6	4.5	4.5	5.6	3.0	2.3	2.8	4.5	3.8	3.1	4.1	5.1
Gap (AutoVision − Human)	+0.9	−2.9	+1.4	+0.3	+3.1	+0.5	−0.5	+2.3	−1.5	−2.2	−2.2	−0.8	+0.8	−1.6	−0.4	+0.5

Figure 16. Comparison of Human and AutoVision (Impact Guesser) evaluations of the four AV concepts. For visual comparison only, AutoVision scores were linearly rescaled from [−100%, +100%] to [0, 6] using ($g = 3 + 0.03\ s$), so that −100% = 0, 0% = 3 and + 100% = 6. This rescaling does not imply that the two scales measure identical constructs.

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users have in it. This may also suggest that some participants may have experienced an illusion of expertise, as they have been working in the automotive industry for a significant period of time.

6. Conclusion

6.1. Findings

This paper presents AutoVision as an original anticipatory design platform developed to support the early-stage design and evaluation of AV concepts under conditions of deep uncertainty. By integrating the SMI and RUI models, AutoVision combines scientific studies, expert judgements and traceable recommendations within a single artefact. While the two underlying models had been introduced separately in previous work, the present study is the first to present their full integration into an operational design platform and to assess its value in comparison with professional designers. This is important because the front end of innovation is precisely the stage at which design freedom is highest, while knowledge about future consequences remains weakest. Conventional brainstorming and agile approaches are useful for generating many ideas quickly, yet they do not necessarily help designers distinguish between desirable and undesirable long-term trajectories. Conversely, impact assessment approaches can help anticipate future effects, but often require a sufficiently stabilised concept and specialised expertise. AutoVision was designed to bridge this gap by combining ideation support with structured anticipatory evaluation.

The exploratory experiment conducted with eight senior designers in a major automotive company yielded three principal findings. First, from the designers' own perspective, a concept generated through the Advisor mode was judged to be at least as convincing as concepts generated by the designers themselves. This result is notable because the participants were highly experienced professionals with decision-making responsibilities in their organisation. It therefore suggests that, in this exploratory setting, a structured knowledge-based platform can generate a concept perceived as competitive with designer-generated alternatives when assessed against explicit strategic criteria. Second, marked divergences appeared between participant evaluations and the platform's evidence-supported assessments, particularly regarding environmental and ethical dimensions. This indicates that even experienced designers may struggle to evaluate concepts whose consequences depend on indirect, systemic and delayed mechanisms extending over decades. Third, the justifications derived from AutoVision were substantially richer, more systematic and more nuanced than the rationales provided by participants, who often relied on immediate, positive or relatively generic arguments.

These findings suggest that professional expertise alone may be insufficient when reasoning about disruptive technologies whose impacts unfold over long-time horizons. Several mechanisms identified in prior literature may help explain these results. Designers may rely on familiar solution patterns and industry routines, thereby reproducing fixation effects (Jansson & Smith 1991; Purcell & Gero 1996) or routine behaviour (Dorst & Cross 2001). They may overestimate the transferability of current experience to radically different futures, thereby underestimating the scale of change (Gates 1999). They may also exhibit bounded

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ethicality (Chugh, Bazerman & Banaji 2005), ethical fading (Tenbrunsel & Messick 2004) or motivated reasoning (Kunda 1990), especially when acknowledging negative impacts implies redesign costs, delayed commercialisation or strategic discomfort. The "advisory" mode may apparently limit creativity (Shah, Kulkarni & Vargas-Hernandez 2000Shah, Smith & Vargas-Hernandez 2003), but it can also help designers avoid falling into all of the aforementioned pitfalls associated with thinking about disruptive technologies whose impacts unfold over long-time horizons.

The originality of the present study lies not only in empirically evaluating a new artefact but also in documenting how cognitive limitations may affect responsible concept evaluation in an industrial context.

6.2. Contributions

The paper contributes to Design Science at several levels. As an artefact contribution, it introduces AutoVision as a novel epistemic support system for responsible concept design. The platform demonstrates how heterogeneous sources of knowledge – scientific studies, expert interpretations, strategic objectives and concept attributes – can be combined into a usable artefact for designers. As a methodological contribution, the paper proposes an experimental protocol comparing designer judgements with transparent platform evaluations and qualitative reasoning traces. As an empirical contribution, it shows that structured anticipatory support can generate concepts perceived as competitive with those of experienced professionals. As a theoretical contribution, it enriches research on design cognition by documenting how professionals may struggle to reason about uncertain, systemic and long-term impacts.

Beyond these direct contributions, the study suggests broader avenues for a discipline of responsible design. First, responsibility requires anticipation without pretending to predict. Designers cannot know the future with certainty, but they can systematically explore plausible impact pathways, second-order effects and uncertainties (Worthington 1982; Von Schomberg 2012; Stilgoe *et al.* 2013). In this respect, AutoVision does not function as an oracle. Rather, it structures available knowledge so that uncertain futures become discussable and comparable. Second, responsibility requires reflexivity and value explicitness. Strategic goals, trade-offs and implicit assumptions should not remain hidden behind technical rhetoric. Responsibility must itself become a design value to be surfaced, debated and operationalised (Friedman, Kahn & Borning 2007; Nihlen, Doorn & van de Poel 2015). The strategic framing used in the experiment – ethical responsibility, environmental responsibility and security – illustrates one possible starting point, but organisations may refine these value categories according to their own context.

Third, responsibility requires inclusion and social responsiveness. Technologies reshape daily life unevenly, often affecting vulnerable populations first or most strongly. Designers, therefore, need mechanisms to account for multiple stakeholders, shifting practices and context-specific consequences (Melles *et al.* 2011; De Saille 2015). The RUI model was developed precisely to bring sociological and expert perspectives into concept reasoning. Fourth, responsibility requires responsiveness and revisability. Design processes must retain the capacity to change direction when new evidence accumulates or when emerging harms become visible (Sattlegger *et al.* 2022). This means that responsibility is not only deliberative but it

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is also operational. Fifth, responsibility requires designing against predictable ethical failure modes. Since bounded ethicality, ethical fading and motivated reasoning are normal human tendencies rather than exceptional flaws, organisations should embed safeguards such as explicit impact reviews, adversarial questioning, structured prompts and accountability mechanisms (Kunda 1990; Tenbrunsel & Messick 2004; Chugh, Bazerman & Banaji 2005). Sixth, responsibility requires treating constraints as generative. Ecological ceilings, safety imperatives and societal boundaries should not be viewed only as restrictions, but as creative drivers of innovation (Auger & Hanna 2019). In this perspective, AutoVision is less a substitute for designers than a structured companion helping operationalise these principles during concept generation and selection.

6.3. Limits and future work

Several limitations should nevertheless be acknowledged. First, the platform's aggregation mechanisms may obscure compensatory effects and privilege impacts that are better documented in literature or expert sources. Some relevant phenomena may therefore be underrepresented. Second, the SMI and RUI models still interact only partially, limiting the representation of cross-effects between environmental, socio-economic and social consequences. For example, a usage change may simultaneously affect employment, emissions and wellbeing in ways not yet fully captured. Third, some dimensions such as security are currently represented narrowly and could be broadened to include reliability, cybersecurity, resilience, misuse scenarios or operational robustness. Moreover, some participant rationales referred to operational safety, whereas AutoVision represented the strategic topic of security only through the "conflict and crime" theme. Comparisons on this dimension should therefore be interpreted cautiously. Fourth, the experiment was exploratory, based on a small and non-representative sample, and group dynamics or charismatic participants may have influenced outcomes. Fifth, participants eventually inferred that Concept X had been generated by the platform because of the density and style of its justifications. Sixth, additional criteria such as economic potential, manufacturability, strategic desirability or regulatory feasibility would also have enriched the evaluation framework.

A last limitation concerns the generalisability of the observed patterns. The empirical study was conducted with a small group of eight senior designers from a single automotive company, within a specific organisational culture and in relation to AV concepts. The results should therefore not be interpreted as statistically generalisable to all designers, firms or sectors. Rather, they should be understood as analytically transferable patterns grounded in mechanisms already documented in prior literature. The cognitive tendencies observed during the experiment – such as fixation on familiar solutions (Jansson & Smith 1991; Purcell & Gero 1996), routine-based reasoning (Dorst & Cross 2001), overconfidence in expert judgment, bounded ethicality (Chugh, Bazerman & Banaji 2005), ethical fading (Tenbrunsel & Messick 2004) and motivated reasoning (Kunda 1990) – are not specific to the automotive context and have been identified across multiple professional decision environments. It is, therefore, plausible that similar difficulties emerge whenever designers or innovation teams must evaluate disruptive products whose impacts are systemic, uncertain and long-term, such as in healthcare technologies, robotics, energy systems, AI services or smart-city infrastructures. However, the intensity

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and expression of these mechanisms are likely to vary depending on sectoral regulation, organisational incentives, design maturity and stakeholder exposure. Future research should consequently examine the replication of these patterns across industries, countries, professional profiles and technological domains, in order to distinguish what is specific to autonomous mobility from what may constitute broader regularities of responsible design under uncertainty.

Future work should therefore proceed in several directions. Larger replications across multiple companies would help determine whether the observed cognitive patterns extend beyond the focal organisation. Cross-sector studies in domains such as healthcare, energy systems, robotics or smart infrastructure would test the transferability of the approach to other disruptive technologies. Longitudinal studies following real design projects could examine whether early use of AutoVision actually changes downstream decisions, project trajectories or impact outcomes. On the platform side, future versions could include richer ontologies of impacts, stronger coupling between the SMI and RUI models, dynamic scenario modules and interfaces allowing designers to challenge or enrich the knowledge base. AutoVision could also serve as a training environment, helping practitioners recognise their own reasoning limitations and institutionalise more reflective design routines (Cash *et al.* 2012).

A final implication concerns the growing role of AI in design support. AutoVision illustrates a form of epistemic augmentation tool that differs substantially from generic large language models. It relies on curated and traceable evidence rather than probabilistic fluency. It provides explicit links between design choices and impact rationales rather than opaque textual plausibility. It is less exposed to hallucinations, fabricated references, instability across prompts or internally inconsistent reasoning. Its knowledge base can be audited, updated and governed according to domain-specific responsibility criteria. More broadly, it suggests that future AI for design should not only generate persuasive outputs but also strengthen judgment, accountability and anticipatory reasoning. The broader lesson of this paper is therefore concise: responsibility in disruptive design may require epistemic augmentation tools.

Supplementary material

The supplementary material for this article can be found at http://doi.org/10.1017/dsj.2026.10074.

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A. Appendix A

A.1. How to formulate recommendations on preferred usages using the RUI model

As explained in Section 3.3.2, a strategy consists of a list of impact indicators for which desirable trends have been identified. For example, a designer may want the stress indicator to decrease, that is passengers experience less stress compared to today when using transportation.

It is from this strategy that recommendations are provided to the user. The aim is to indicate usages to promote and usages to avoid. For example, recommending the usage of "sleeping in the vehicle" which can help reduce stress according to experts.

As output, the Advisor mode provides three metrics for each usage of the autonomous vehicle:

- The majority influence M_u, which indicates whether the usage should be favoured ($M_u = 1$) or avoided ($M_u = -1$).
- The number of impacts n_u that experts have associated with this usage.
- The conflict coefficient k_u, which expresses whether there is consensus ($k_u \approx 0$) among the experts or not ($k_u \approx 1$).

Examples of interpretation for these three metrics are provided in Table A1. The following paragraphs detail their calculation.

To calculate the majority influence M_u, the average intensity $\overline{Q^*_{I\,u}}$ of impacts caused by the usage u (according to the experts) is first calculated (Equation A1). This average is calculated with respect to the direction of trends selected by the user: for each impact, if trend (T) is the same as the trend selected by the user (T'), then the average intensity is positively influenced. The average intensity is normalized and ranges from -1 (the usage only causes negative impacts) to 1 (the usage only causes positive impacts).

Table A1. Example of calculating and interpreting M_u, n_u and k_u metrics based on five usages, following the selection of one or more social impact trends by a user

Usage (u_x)	Majority influence (M_{u_x})	Total number of impacts (n_{u_x})	Conflict coefficient (k_{u_x})	Interpretation
u_1	1	2	82%	There is little data on usage 1, and the impacts contradict each other (high conflict). We cannot give importance to the majority influence.
u_2	1	31	18%	Usage 2 clearly favours the selected trends.
u_3	−1	3	0%	There is little data on usage 3, but all three impacts indicate the same trend (no conflict). We can say that usage 3 could unfavourably impact the selected trends.
u_4	−1	28	94%	There is a lot of data on usage 4, but the impacts contradict each other (high conflict). We cannot conclude on the majority influence.

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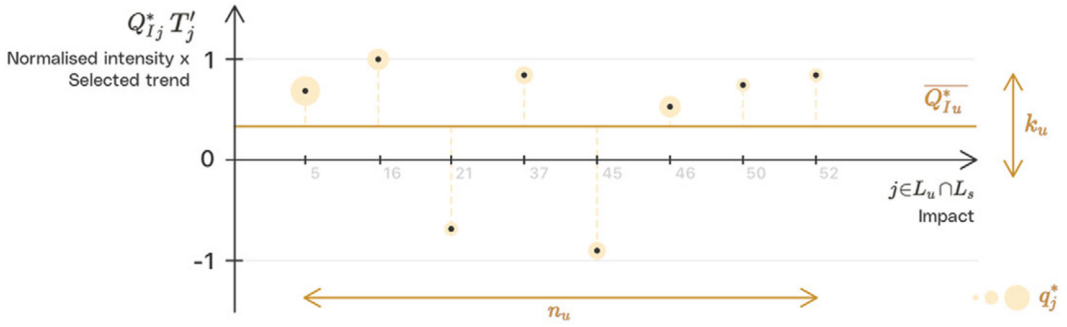


Figure A1. Graphical representation of average intensity ($\overline{Q^*_{I\,u}}$), conflict (k_u) and total number of impacts (n_u), weighted by certainty (q^*_j), for a given usage u. The size of the circles represents the level of certainty $q^*_j \in [0,1]$.

$$\overline{Q^*_{I\,u}} = \frac{\sum_{j \in L_u \cap L_s} Q^*_{Ij}\,\mathrm{T_j}\,T'_j q^*_j}{\sum_{j \in L_u \cap L_s} q^*_j} \tag{A1}$$

- L_u is the subset of impacts that are influenced by the usage u.
- L_s is the subset of impacts corresponding to the indicators selected by the user.
- T_j is the trend of impact j.
- T_j' is the trend selected by the user for impact j.
- q^*_j is the normalised certainty of impact j.
- Q^*_{Ij} is the normalised intensity of impact j.

Depending on the sign of this average intensity, it is then possible to calculate the majority influence (Equation A2).

$$M_u = \mathrm{sgn}\left(\overline{Q^*_{I\,u}}\right) \tag{A2}$$

The total number of impacts for the usage u corresponds to the set of impacts influenced by this usage (L_u) and selected by the user (L_s) (Equation A3).

$$n_u = |L_u \cap L_s| \tag{A3}$$

Finally, the conflict coefficient k_u (Equation A4) is equivalent to a weighted standard deviation of intensity $Q^*_{I\,u}$.

$$k_u = \sqrt{\frac{\sum_{j \in L_u \cap L_s} q^*_j \left(Q^*_{Ij} T_j T'_j - \overline{Q^*_{I\,u}}\right)^2}{2\frac{n_u - 1}{n_u} \sum_{j \in L_u \cap L_s} q^*_j}} \tag{A4}$$

Figure A1 graphically represents the average intensity ($\overline{Q^*_{I_u}}$), the conflict (k_u) and the number of impacts (sn_u).

B. Appendix B

B.1. How to formulate recommendations on preferred validity domains using the SMI model

As explained in Section 3.3.2, a strategy consists of a list of impact indicators for which desirable trends have been identified. For example, a designer may want the CO_2 emissions indicator to decrease.

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It is from this strategy that recommendations are provided to the user. The aim is to indicate validity domains to promote and to avoid. For example, recommending a shared mode of use that can help reduce CO_2 emissions, according to scientific studies.

In the output, the Advisor mode provides three metrics for each validity domain:

- The majority influence M_v, which indicates whether the validity domain should be favoured ($M_v = 1$) or avoided ($M_v = -1$).
- The number of impacts n_v associated with this validity domain by the studies.
- The conflict coefficient k_v, which expresses whether there is consensus among the studies ($k_v \approx 0$) or not ($k_v \approx 1$).

Their operation is similar to what was presented in the previous section (Table A1). The following paragraphs detail their calculation.

To calculate the majority influence M_v, the average of values $\overline{V_v^*}$ of impacts linked to the validity domain (according to studies) is first calculated (Equation A5). This average is calculated with respect to the direction of trends selected by the user: for each impact, if the value is in the same direction as the trend selected by the user (T'), then the average is positively influenced. The average of values is normalized and ranges from -1 (the validity domain is only linked to negative impacts) to 1 (the validity domain is only linked to positive impacts).

$$\overline{V_v^*} = \frac{\sum_{j \in L_v \cap L_s} V_j^* T_j' q_j}{\sum_{j \in L_v \cap L_s} q_j} \tag{A5}$$

- L_v is the subset of impacts that are linked to the validity domain v.
- L_s is the subset of impacts corresponding to the indicators selected by the user.
- V_j^* is the value of impact j (normalised by the highest value of the corresponding indicator).
- T_j' is the trend selected by the user for impact j.
- q_j is the certainty of impact j (calculated based on the impact factor, number of citations and whether the study from which the value has been extracted is peer-reviewed or not).

Depending on the sign of this average value, it is then possible to calculate the majority influence (Equation A6).

$$M_v = \mathrm{sgn}\left(\overline{V_v^*}\right) \tag{A6}$$

The total number of impacts for the validity domain v corresponds to the set of impacts linked to this validity domain (L_v) and selected by the user (L_s) (Equation A7).

$$n_v = |L_v \cap L_s| \tag{A7}$$

Finally, the conflict coefficient (k_v) (Equation A8) is equivalent to a weighted standard deviation of values V_j^*.

$$k_v = \sqrt{\frac{\sum_{j \in L_v \cap L_s} q_j \left(V_j^* T_j' - \overline{V_v^*}\right)^2}{2\frac{n_v - 1}{n_v} \sum_{j \in L_v \cap L_s} q_j}} \tag{A8}$$

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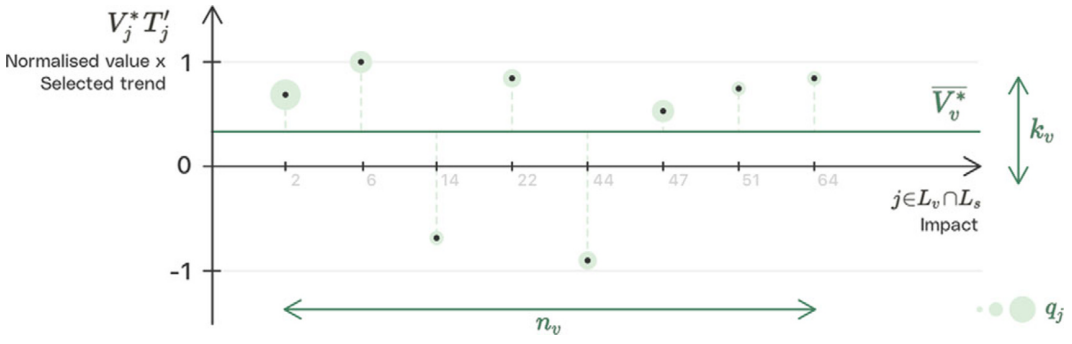


Figure B1. Graphical representation of the average of normalised values ($\overline{V_v^*}$), conflict (k_v) and total number of impacts (n_v) by certainty (q_j), for a given validity domain (v). The size of the disks represents the level of certainty $q_j \in [0,1]$.

Figure B1 graphically represents the average of normalised values ($\overline{V_v^*}$), conflict (k_v) and the number of impacts (n_v).

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