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Toward inclusive decision making: A systematic introduction of the mass-participation decision support framework

He Huang

Laboratory for Energy Systems Analysis (LEA), Paul Scherrer Institute, Forschungsstrasse 111, Villigen, 5232, Switzerland

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ABSTRACT

Inclusive decision-making processes are increasingly recognized as critical for legitimacy and effectiveness in complex management and public policy contexts. However, current decision support methodologies offer limited guidance on systematically involving very large and diverse stakeholder groups. This paper introduces the concept of Mass-Participation Decision Support (MPDS) as a new paradigm for decision aiding, aiming to dramatically broaden stakeholder engagement in complex decisions. We outline the theoretical underpinnings of MPDS in stakeholder theory and identify a participation gap whereby mass stakeholder groups such as the general public are often excluded from meaningful input. We then propose a structured, tiered MPDS framework that differentiates stakeholder involvement into multiple levels – from broad information sharing and light consultation with the masses, to collaborative modeling with selected representatives, up to empowered decision-making by authorities. We illustrate how this framework addresses shortcomings of traditional large-group decision approaches and enhances both the breadth of democratic participation and the depth of analytical rigor. Key enabling techniques are discussed, including clustering methods to handle large-scale preference data, criteria selection procedures, structured group evaluation frameworks, and soft consensus strategies for conflict resolution. A case study in Brussels' construction logistics planning is presented to demonstrate the feasibility and benefits of MPDS in practice. We conclude that MPDS offers a novel, inclusive decision support framework that can improve legitimacy, stakeholder learning, and acceptance of decisions, and we call for further research to refine and apply this approach in various management domains.

1. Introduction

Complex decisions in management and public policy increasingly demand not only technical rigor but also legitimacy through broad stakeholder participation. The concept of "mass participation", familiar in contexts like sports, and health (Byrne et al., 2006; McVinnie et al., 2023; Murphy et al., 2018), has been largely absent in decision science. It is mostly discussed in a decision-making of law or political events (Itten and Mouter, 2022; Kaase, 1990; Rossi, 1997). In practice, participatory decision-making efforts are often limited to small groups or late-stage consultations, which can render them tokenistic and insufficient. For example, in climate policy-making the majority of planning still occurs in expert circles, with public input solicited only at a later stage as a formality (Itten and Mouter, 2022). Such constrained approaches fall short of true mass engagement. Empirical studies have found that insufficient or superficial participation often triggers public backlash, the classic "Not in My Backyard" (NIMBY) syndrome for example, leading to protests and policy failures in domains ranging from urban planning to environmental management (Abas et al., 2023). A case in point is Brussels' recent "Good Move" mobility plan: despite its technical merits in reducing traffic and pollution, the plan's rollout met with fierce community opposition and protests that forced authorities to halt and revise the implementation (Brussels Mobility, 2023). Even a public forum intended to reconcile stakeholders devolved into chaos and shouting, as disaffected residents hijacked the discussion and prevented any constructive dialogue (The Brussels Times, 2024). This breakdown of the participatory process vividly illustrates the risks of inadequate structure in large-scale engagement. Together, these observations underscore an urgent need for decision-support approaches that can harness broad, diverse stakeholder input in a well-organized way, thereby improving both the quality and legitimacy of complex decisions.

To bridge this gap, we propose the notion of Mass-Participation Decision Support (MPDS), a decision-aiding paradigm designed to inclusively engage a broad base of stakeholders in complex decision-making (Huang, 2023b). MPDS aims to reconcile technical analytical rigor with democratic inclusivity by structuring participation at scale.

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It builds on the premise that modern communication technologies and carefully designed processes can enable hundreds or thousands of people to contribute meaningfully to a decision. Notably, recent research in participatory democracy has begun exploring how small deliberative "mini-publics" (e.g., citizen panels or juries) can be combined with large-scale "maxi-public" input via digital platforms to increase legitimacy (Itten and Mouter, 2022). These efforts echo the motivation behind MPDS: to move beyond limited consultation and give voice to the wider affected public in a manageable way. In essence, MPDS provides an overarching framework to incorporate mass stakeholder knowledge, preferences, and values into decision analysis, thus addressing the shortcomings of traditional approaches. This paper articulates the theoretical basis, core principles, and an integrative framework for MPDS, along with guidance for its practical implementation. By formalizing this paradigm, we seek to fill a critical gap in decision science and offer a path toward decisions that are both well-founded and broadly supported. We focus on Multiple Criteria Decision Aiding (MCDA) as the initial methodological context for demonstrating MPDS. MCDA is well-suited because it systematically evaluates alternatives against multiple, potentially conflicting criteria, enabling decision-makers to balance diverse objectives. However, the richness and complexity of MCDA also mean that it benefits greatly from structured group input – especially when different stakeholders or stakeholder groups value criteria differently (Huang et al., 2023). In current practice, MCDA applications typically involve a limited number of decision-makers or experts, which may not capture the full spectrum of stakeholder preferences. Thus, to apply MCDA in multi-stakeholder contexts, an inclusive and well-organized participation process is needed to gather and synthesize dispersed knowledge and value judgments. MPDS complements the analytic strength of MCDA by providing that structured mass-participation process. In our examples, we draw on a particular MCDA variant, the Multi-Actor Multi-Criteria Analysis (MAMCA) approach, to illustrate how MPDS can be operationalized. While our illustrations center on MCDA (and specifically MAMCA), the underlying MPDS principles – a hierarchical and structured inclusion of mass stakeholders – are intended to generalize to other decision support methods as well. We envisage that any complex decision process requiring stakeholder buy-in could benefit from the MPDS paradigm, from strategic planning and policy design to large-scale project appraisals.

The remainder of this paper is organized as follows. Section 2 provides the theoretical background and related work, laying out the conceptual foundations of MPDS and situating it in the context of existing participatory decision-making methods. Section 3 introduces the core principles of MPDS, detailing the key design tenets that enable effective mass stakeholder involvement. Section 4 then presents an integrative framework for MPDS, showing how these principles coalesce into a coherent decision-support approach and describing the architecture of an MPDS process. Section 5 offers guidance on implementing MPDS in practice, including methodological steps, tools, and practical considerations for practitioners. We also discuss illustrative examples in the MCDA context to demonstrate how MPDS can be applied. Section 8 concludes the paper by summarizing the contributions, highlighting the implications of adopting MPDS, and suggesting directions for future research and practice.

2. Theoretical foundation: stakeholder theory and the participation gap

Our MPDS framework is grounded in classic stakeholder theory. Freeman's seminal definition describes stakeholders as "those who are affected by or can affect a decision", encompassing any individual or group with a significant interest in or influence on the outcome (Parmar et al., 2010). In complex decisions, there are often multiple stakeholder groups with differing, even conflicting, interests and objectives (Kahane et al., 2013). This stands in contrast to the traditional notion of a single decision-maker (DM): in practice, the "DM" is usually just one stakeholder group (often an authority or sponsor) among many. The challenge is how to account for the pluralism of stakeholder values in a decision that ultimately one entity (e.g., a government official, corporate manager, etc.) must endorse. Many decision processes attempt stakeholder involvement through methods like workshops, forums or advisory committees with selected stakeholder representatives. Engaging stakeholders in this way can yield significant benefits: it helps participants understand each other's priorities, uncovers potential conflicts or consensus, and can increase the acceptance of the final decision. For example, structured involvement of multiple actors via methods like MAMCA has been shown to improve support for the chosen alternative by ensuring each stakeholder's objectives are considered (Huang et al., 2021). In an ideal scenario, such engagement leads to decisions that are more broadly accepted and thus easier to implement.

Beyond traditional stakeholder management, deliberative democracy offers a complementary theoretical lens (Habermas and McCarthy, 1977). Deliberative democracy argues that decisions gain legitimacy through inclusive, reasoned debate among diverse citizens, not merely top-down authority (Gutmann and Thompson, 2004). In other words, everyday people (not just organized interest groups or elites) should be involved in public decision-making through dialogue and collective reasoning. This perspective aligns with stakeholder theory by emphasizing that those affected by a decision deserve a voice in shaping it. Deliberative processes—such as citizens' assemblies, consensus conferences, or deliberative polling—seek to bring together a microcosm of the broader public to discuss issues and negotiate trade-offs. By facilitating face-to-face (or online) discussions among lay citizens of differing viewpoints, these approaches can uncover shared values, educate participants about complex issues, and yield more considered judgments. Importantly, deliberation helps incorporate the "mass stakeholder" like the general public or large community into decision-making in a more meaningful way than traditional consultation. It moves beyond one-way input collection and toward two-way dialogue, addressing the knowledge gaps and isolation that often plague mass surveys. The ethos of deliberative democracy thus directly tackles the participation gap by expanding meaningful public participation in political decisions rather than confining influence to a narrow set of actors.

Equally pertinent is the concept of procedural justice, which highlights the impact of fair process on stakeholder acceptance. Social psychology research indicates that the perceived fairness of public participation procedures can affect public satisfaction as much as the substantive outcome of the decision (DeCaro and Stokes, 2013). In practical terms, people are more willing to accept a decision if they believe the process was inclusive, transparent, and treated them with respect (Pless and Maak, 2004). Key elements of procedural justice include having a voice in the process (participation), neutral and consistent rules, and dignified treatment of all parties. When these conditions are met, stakeholders are likelier to view the decision as legitimate and binding. Conversely, if affected groups feel sidelined or see the process as biased, their trust in the outcome erodes. This principle has been borne out in public administration and environmental management contexts: processes heavy on technical expertise but light on genuine public input often face high levels of public dissatisfaction and conflict, even when they comply with all legal requirements. Thus, beyond achieving the "best" technical solution, decision-makers must also focus on the fairness and transparency of how the decision is made, recognizing that process legitimacy is integral to implementation success.

However, in numerous real-world contexts, especially in public sector decisions, there exists a large and heterogeneous stakeholder group that is systematically left out of deep participation. We term this the mass stakeholder group, exemplified by "the general public" or a broad community of citizens affected by a policy. Traditional stakeholder engagement usually deals with relatively small or organized groups (e.g., employees, customer segments, local businesses) that can nominate a representative to participate in workshops. But a mass stakeholder group (for instance, city residents at large) may number in the thousands or millions, with diverse sociodemographic backgrounds and viewpoints. Such a group cannot be adequately represented by just one or two individuals without significant loss of diversity. Indeed, as Arnstein's classic ladder of participation noted, involving only a few hand-picked citizens as a proxy for the broader public tends to be tokenistic (Arnstein, 1969). These few lack the numbers and legitimacy to truly reflect the heterogeneity of the larger community.

A cautionary example is the recent Good Move regional mobility plan in Brussels (Brussels Mobility, 2023). This comprehensive traffic plan, developed over several years, involved many traditional stakeholder organizations, e.g., experts, NGOs, and municipal officials. It was well-intentioned in its sustainability and livability goals. Yet it failed to effectively capture or integrate the genuine preferences and concerns of the general public, the very people who would be most affected by neighborhood traffic changes. In effect, the authorities treated the public as a monolithic mass stakeholder, giving minimal opportunities for ordinary residents to shape the plan. As a result, when implementation began, the plan faced fierce public backlash including petitions, protests and even civil disobedience. Citizens acknowledged the plan's good intentions, but as one community leader put it, "it is the method that we dispute (The Brussels Times, 2024)." The absence of a trusted, inclusive process for everyday residents to deliberate on and influence the plan led to a crisis of legitimacy. In terms of social license to operate, the project lacked the informal but crucial approval of the community at large. Social license refers to the acceptance or approval that organizations (or policies) receive from local stakeholders beyond formal legal compliance (Demuijnck and Fasterling, 2016). Without that community buy-in, even legally sanctioned plans can falter. Indeed, Brussels' Good Move lacked a social license among citizens and was ultimately met with enough resistance to force authorities to halt or significantly water down parts of the plan. Good Move's struggles highlight the high cost of an inadequate engagement strategy for mass stakeholders. They underscore that even "game-changing policies only work if citizens are fully involved in designing them".

Still, sheer size and internal diversity make traditional representation approaches ineffective for mass stakeholder groups. This gap manifests in practice as a participation deficit: large publics are often only superficially consulted, if at all, in complex decisions.

Two prevailing strategies exist to involve mass stakeholders, each with notable limitations:

- Large-Scale Surveys: When faced with a mass stakeholder group, decision-makers often resort to surveys or polls to collect public input and make decisions. It is quite popular in the MCDA studies, for example Borna and Beheshtinia (2022); Ignaccolo et al. (2019); Ma et al. (2023). While surveys can reach many people, this approach has notable drawbacks:
  - It lacks interaction and deliberation among participants. Stakeholders respond in isolation, without the benefit of learning from each other or negotiating trade-offs, leading to uninformed inputs.
  - Meaningfully engaging with complex decision criteria via a simple questionnaire imposes a high cognitive burden on respondents; without background knowledge or context (which surveys rarely provide in depth), the reliability and depth of the collected preferences are questionable. Indeed, defining evaluation criteria or priorities is especially difficult for large citizen groups, so survey responses may be shallow or inconsistent.
- Representative Participation: Alternatively, decision-makers sometimes invite a small number of citizen representatives from the larger public to join focused workshops (e.g., a few residents selected to speak for all), for example in MCDA cases (Aljohani and Thompson, 2018; Lode et al., 2021). This allows for dialogue and deeper input, but raises issues of representativeness and legitimacy.
  - A mass stakeholder group's extreme heterogeneity means that one or two individuals cannot possibly mirror the full spectrum of perspectives and concerns in the population. Important viewpoints will inevitably be left out.
  - Moreover, the selection of those "representatives" is often ad hoc or opaque. For instance, volunteers or vocal activists might self-select into the process, which can bias the discussion. Without a systematic and transparent selection mechanism, the broader public may not trust that these representatives truly speak on their behalf.

In summary, classic stakeholder theory and related frameworks like deliberative democracy illuminate the importance of broad, meaningful participation in complex decisions. When large public groups are excluded or only superficially engaged, a participation gap results: eroding the perceived fairness (procedural justice) and risking the loss of public support (social license to operate). We summarize the key theoretical lenses in Table 1.

Bridging this gap requires moving beyond perfunctory surveys or token representatives toward more systematic, inclusive models of engagement. Our MPDS framework seeks to provide precisely that: a structured approach to incorporate the voices and values of mass stakeholders into decision-making, so that the final decision can claim both technical merit and democratic legitimacy.

3. MPDS framework: structured and tiered participation

The core of MPDS is a structured, tiered participation framework that stratifies stakeholder involvement according to their roles, information needs, capacities, and functions in the decision process. This design is inspired by established models of participation, such as Arnstein's ladder and the IAP2 spectrum, which distinguish levels of stakeholder engagement from mere information-sharing up to full decision power (Arnstein, 1969; Engagement, 2018). In line with insights from participatory decision-making literature (Marttunen et al., 2015), MPDS acknowledges that while broad and deep stakeholder participation is ideal, practical constraints require a thoughtful structuring. We delineate four key tiers of participation, each corresponding to a category of actors in the decision process and a specific "level of participation" granted to them. These levels can be summarized as Information, Consultation, Collaboration, and Empowerment – implemented in a cumulative way (each higher tier builds on inputs from below) and a complementary way (different stakeholders play different roles). Below, we describe each tier in the context of a large-scale MCDA decision process:

1. Tier 1: (Mass) Stakeholder Group – Information and Light Consultation. This bottom tier consists of the broad population of stakeholders who are impacted by the decision but who, due to sheer numbers, cannot all be deeply involved individually. Their role in MPDS is primarily as recipients of information and as providers of initial preference signals, with a participation level focused on Information (plus light Consultation). *Rationale & Modus Operandi:* Given the group's size and highly heterogeneous makeup, it is neither practical nor cognitively reasonable to expect all members to provide detailed inputs on complex trade-offs (Huang et al, 2024c). Research shows that fully engaging hundreds or thousands of stakeholders in rigorous MCDA is challenging (Huang et al., 2021; Marttunen et al., 2015). Instead, MPDS emphasizes two responsibilities at this level:
   (1) Ensuring the right to know: Mass stakeholders are kept fully informed of the decision context, objectives, and alternatives through accessible channels (e.g., public websites, brochures, community meetings, social media updates). Information is presented clearly and transparently to educate this broad audience about the stakes and options. This fulfills a fundamental democratic principle that people have the right to understand decisions that affect them (Popovic, 1992). Notably, informing alone is considered a basic but insufficient form of participation, so MPDS treats it as a foundation on which higher engagement

Table 1
Key theoretical lenses and their implications for the participation gap.

Theoretical lens	Core idea	Participation implication	Gap / risk identified
Stakeholder Theory (Freeman and Phillips, 2002)	Stakeholders are all who affect or are affected by the decision.	Decisions should reflect the plurality of stakeholder values.	Mass stakeholders remain under-represented in typical processes.
Deliberative Democracy (Habermas and McCarthy, 1977)	Legitimacy arises from inclusive, reasoned public deliberation.	Encourages dialogue and joint reasoning among diverse citizens.	Survey-only or expert-led models lack deliberation and inclusivity.
Procedural Justice (Tyler, 2003)	Perceived fairness of the process drives acceptance and compliance.	Calls for transparent, respectful, and inclusive procedures.	Tokenistic engagement erodes legitimacy and harms acceptance.
Social License to Operate (Morrison, 2014)	Community's informal approval beyond legal compliance is critical.	Ongoing public acceptance is needed for smooth implementation.	Ignoring public sentiment risks backlash.

will build, ensuring that providing information is not a one-way or tokenistic exercise.

(2) Capturing basic preferences at low burden: Simple, carefully-designed input tools gather the group's core concerns and initial preferences without overwhelming them. These could be very short surveys, polls, or voting exercises focusing on key questions (for example, asking citizens to rank a small set of objectives, or select the one or two criteria they care about most). The interaction is kept intuitive to minimize cognitive load, participants might answer a few high-level questions rather than perform a full multi-criteria weight elicitation. The goal is to obtain broad coverage data that, while coarse, faithfully reflects the major priorities and "red lines" of the community. By the end of this stage, practitioners should have a baseline map of what matters most to the wider public, grounded in a dataset that is as representative as possible of that population with attention to demographic diversity in responses. For instance, outreach efforts should strive to hear from different demographic and socioeconomic groups, potentially using stratified sampling to ensure inclusivity (Ngubane et al., 2024). The result of Tier 1 is a synopsis of public values and concerns, which will feed into subsequent tiers.

2. Tier 2: Experts – Consultation and Co-Design. This tier consists of domain experts and technical analysts who possess specialized knowledge relevant to the decision (e.g., engineers, subject-matter scientists, policy analysts). Their role is to inform and help construct the decision model. The participation level for experts is primarily "Consultation", with elements of co-design in collaboration with decision process practitioners and possibly some stakeholders. *Rationale & Modus Operandi:* Experts are consulted to ensure the decision's technical foundation is sound and evidence-based. Based on the information collected from the mass stakeholders and other sources such as prior studies, experts work on designing or refining key decision elements: for example, formulating a comprehensive set of decision alternatives, defining meaningful criteria for evaluation, and building appropriate assessment models or simulations (Jonassen, 2012). In MPDS, experts do not operate in an ivory tower; rather, they work in close coordination with the practitioners of the process and often interact with representatives of stakeholder groups to incorporate practical knowledge. We encourage a co-design ethos at this level (Evans and Terrey, 2016). For instance, experts might hold focus groups or interviews with some stakeholders, or iterate on draft alternatives and criteria with input from practitioners, to ensure the decision framework is both scientifically valid and contextually relevant. In some cases, stakeholders themselves can be a source of criteria or options (as seen when participatory processes directly consult stakeholders to solicit alternatives and evaluation criteria). By the end of this stage, a decision model is in place: a well-documented set of alternatives to consider and criteria by which to judge them, ready for evaluation. This "expert + stakeholder co-designed" model becomes the backbone for the next tier's deliberations.

3. Tier 3: Stakeholder Representatives – Collaboration in Preference Modeling. This tier is composed of selected representatives from each stakeholder segment, including representatives of subgroups from the mass stakeholder population. These individuals are invited to participate in a structured group decision-making exercise as proxies for their communities. The participation level here is "Collaboration", as stakeholders actively collaborate in the analysis. *Rationale & Modus Operandi:* To make large-scale participation manageable, MPDS employs a divide-and-represent strategy. The initial data from the mass stakeholders (Tier 1) is analyzed. Using clustering or segmentation techniques, we can identify relatively homogeneous subgroups within the diverse population (Veerappa and Letier, 2011). In other words, the broad public may be segmented into a few clusters of people with similar priority patterns. For example, one subgroup of citizens might prioritize "reducing noise pollution" while another cares more about "minimizing cost". These subgroup insights guide a rigorous selection of stakeholder representatives. Rather than arbitrarily picking one or two citizens, MPDS calls for a transparent procedure to choose individuals who can credibly voice the preferences of each identified subgroup, as well as representatives of other key stakeholder categories (e.g., business community, NGOs, indigenous groups, etc., as appropriate to the case). This could be done via stratified selection within each cluster, nominations or elections within stakeholder groups, or other fair methods.

Although privacy regulations may prevent selecting representatives directly on the basis of the data they submitted, Tier 1 outputs still provide those representatives with clear insight into the priorities of their constituencies. The aim is to mitigate the pitfall of "handpicking a few worthy citizens" by instead "systematically ensuring representativeness" (Irvin and Stansbury, 2004). All selected representatives then participate in a structured workshop or series of workshops, typically facilitated by decision analysts, to perform a detailed evaluation of the alternatives using the chosen decision-support method (Marttunen et al., 2015). For example, in an MCDA setting, representatives would be guided through a process of expressing their preferences: they might assign weights to criteria and evaluate how each alternative scores on each criterion, using techniques that they are briefed on or trained in during the workshop. This is essentially a stakeholder-involved group decision-making session, where each representative brings the perspective of their constituency into a collective model (Huang et al, 2025b). Deliberation is a key feature of this stage: participants share their reasoning, learn about others' viewpoints, and can discuss and adjust their judgments accordingly (Belton and Pictet, 1997). The outcome is a set of preference models or evaluated rankings of alternatives, one per representative or perhaps one per subgroup, that reflect each stakeholder group's view of the decision problem. These results can then be aggregated, compared, or visualized side-by-side to reveal areas of consensus and disagreement among the stakeholder groups. The collaborative nature of this stage ensures high-quality input: representatives spend significant time grappling with the decision's complexities, which leads to more informed and nuanced preferences than the quick impressions captured in Tier 1. In essence, Tier 3 provides what the large-scale survey alone could not: informed, deliberative, and context-rich preference modeling, grounded in the broader public's values.

4. Tier 4: Decision Makers – Empowerment and Consensus-Building. The top tier comprises the formal decision-maker(s) who are authorized to make the final choice. This could be a public official or committee, a corporate executive board, a project steering committee, etc. In MPDS, their participation level is Empowerment, meaning they ultimately decide, but with a strong emphasis on transparency, accountability, and consensus-building based on the inputs from the lower tiers. *Rationale & Modus Operandi:* By the time the process reaches this tier, decision makers are presented with a wealth of structured information: the set of alternatives and criteria (from Tier 2 experts), and the evaluation results from the stakeholder representatives' collaborative analysis (Tier 3). The decision makers' first responsibility is to thoroughly understand this information. Often, they will engage in dialogue or debriefing sessions with the representatives and experts, effectively a facilitated workshop at the end of the process, to discuss the outcomes and their implications. The goal at this stage is to achieve as much consensus or mutual understanding as possible before a final decision is made. If the stakeholder representatives' evaluations showed general agreement on a top-ranked alternative, the decision maker can feel confident endorsing that option. If there were significant divergences in the rankings or criteria trade-offs, this tier may involve applying "soft" consensus techniques, which will be discussed later in the paper, to mediate differences (Dong et al., 2016). For example, the decision makers might use a decision-support visualization that highlights the distance between stakeholder groups' positions, and then explore adjustments or even modified alternatives to see if a higher overall agreement can be reached (Huang and Siraj, 2024; Oral et al., 2023). They might ask the group to consider tweaks to an alternative or propose a hybrid solution that blends features of multiple options, in pursuit of a broadly acceptable outcome. Ultimately, empowered with both the analytical results and a keen sense of each stakeholder group's stance, the decision maker(s) exercise their judgment to select the course of action. The final decision is made by those with formal authority, but crucially, the MPDS process ensures this decision is informed by a transparent trace of stakeholder inputs. Ideally, the chosen alternative will be the one that has the most support (or least opposition) across the spectrum of stakeholders. Even if not everyone gets their first choice, the inclusive and systematic nature of the process builds legitimacy for the outcome. Stakeholders can see that their contributions via surveys, workshops, and discussions had a clear pathway to influence the final decision, which enhances the decision's credibility and acceptability (Coutu et al., 2019).

Some key characteristics distinguish the MPDS framework. Fundamentally, we provide a layered information flow. The process is engineered so that data, preferences, and insights move bottom-up in an orderly sequence, while feedback and transparency cascade top-down. Signals collected from the broad public in Tier 1 shape how experts frame the decision in Tier 2 and how stakeholder segments are formed for representation in Tier 3. In turn, the refined evaluations produced by stakeholder representatives in Tier 3 become the core evidence for deliberation at Tier 4. This progressive distillation preserves the voice of the masses and helps MPDS avoid the tokenism that Arnstein warned against: informing or consulting stakeholders has value only if those inputs genuinely influence subsequent choices (Arnstein, 1969). Equally important, decisions and rationales flow back to the lower tiers, so participants can see how their contributions mattered, fulfilling the promise of participation and aligning with best-practice guidelines such as the IAP2 principle of reporting back to the public.

A second characteristic is role differentiation coupled with cross-tier interaction. MPDS stratifies roles for manageability, yet the tiers are permeable rather than siloed. Individuals from the mass public may "graduate" to the representative tier, and experts may collaborate with those representatives during alternative development or criteria refinement. If new information emerges, or if representatives need clarification, feedback loops allow tiers to interact and adjust. For example, should Tier 1 feedback reveal an overlooked criterion, experts can revise the model even while Tier 3 deliberations are underway. Similarly, representatives may request additional technical analysis, or experts may brief them to build shared understanding. By institutionalizing these communication channels, MPDS remains responsive and capable of self-correction, thereby improving the quality and legitimacy of the decision process. Ultimately, this framework provides a temporal phasing and resource planning approach. MPDS unfolds over multiple stages, from broad outreach and data collection, expert modeling, intensive stakeholder workshops, to final consensus-building. It demands careful scheduling and adequate resources at every phase. A recent large-scale MCDA in environmental management, for instance, required roughly eleven months from the initial survey to the final decision meeting, illustrating the time needed to do justice to each step (Ngubane et al., 2024). Although this phased approach is more time-intensive than a single public meeting or survey, it yields a decision that has been examined from many angles and is better prepared for implementation. Participants acquire shared understanding as a form of social learning. This reduces the risk of backlash or unforeseen issues. In short, MPDS is an upfront investment in a comprehensive, iterative procedure that ultimately delivers more robust and broadly supported outcomes.

The MPDS architecture is explicitly bi-directional. In the bottom-up direction, raw stakeholder signals gathered at Tier 1 (e.g., survey responses, priority rankings) are cleaned and encoded as structured artifacts such as salience scores, cluster labels, and medoid profiles that feed forward into Tier 2 methodologies (criteria preprocessing and alternative specification). Tier 2 then outputs a validated criteria shortlist, defined alternatives, and a performance matrix with uncertainty bounds, which populate Tier 3 decision templates for representative weighting and scoring. These Tier 3 judgments are subsequently synthesized for Tier 4 using robustness and consensus diagnostics, thereby converting diffuse inputs into decision-ready evidence. The information feeding is also illustrated in Fig. 2.

Complementary top-down feedback flows return explanations, model updates, and accountability to all contributors. Decision rationales and monitoring commitments are communicated to representatives and experts, while plain-language "evidence-of-use" summaries are reported to mass participants. At every hand-off, datasets and documents are versioned and cross-referenced, so that any higher-tier output can be traced to lower-tier inputs and, conversely, any decision can be explained in terms of the evidence and value judgments that produced it. In this way, the MPDS pipeline functions not only as a sequence of methods, but as an information architecture that preserves end-to-end traceability and auditability.

Fig. 1 schematically illustrates the MPDS architecture. In the figure, one can envision a four-layer pyramid or flow diagram: the broad Mass Stakeholder Group forms the wide base (Tier 1), funneling information upward into the narrower Expert layer (Tier 2), then to the smaller group of Stakeholder Representatives (Tier 3), and finally up to the Decision Makers at the apex (Tier 4). Arrows indicate how information and preferences travel upward from the base, while feedback and transparency measures flow downward from the top. This visual emphasizes how MPDS structurally channels a very large, diffuse public input into a focused, decision-ready format, while maintaining linkages between all levels.

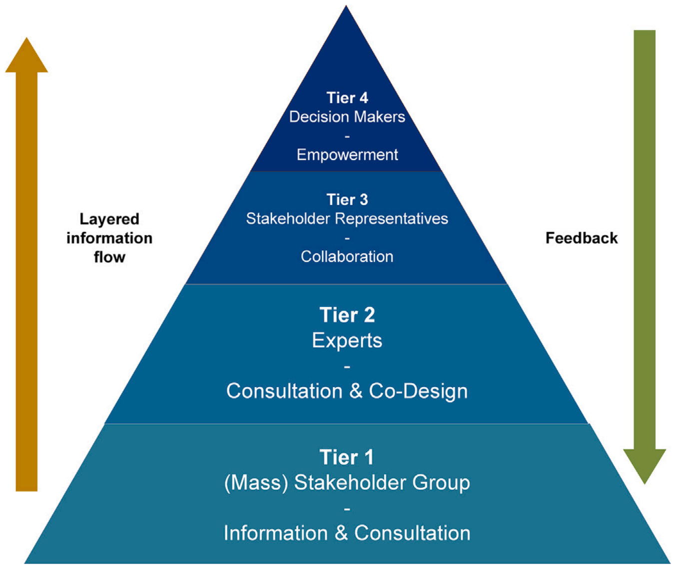

Fig. 1. Conceptual schematic of the MPDS tiered participation framework. Conceptual schematic of the MPDS tiered participation framework. The four tiers link (1) mass stakeholders—Information & light Consultation, (2) experts—Consultation/co-design, (3) stakeholder representatives—Collaboration in MCDA (e.g., MAMCA), and (4) decision makers—Empowerment. Arrows depict the bottom-up flow of inputs and the top-down feedback/reporting that closes the loop.

4. Enabling techniques and methods

The Mass-Participation Decision Support (MPDS) framework can leverage different enabling methodologies to manage large-scale group decision processes. Each method addresses a specific need within the tiered MPDS structure and collectively they ensure that diverse participant inputs are meaningfully incorporated. In this section, we detail four important methodologies: Mass-Participation Clustering, Criteria Preprocessing, Structured Group Decision Frameworks, and Soft Consensus Reaching—explaining their roles in MPDS, underlying principles, input-output flows, implementation strategies, and examples of use in large-scale participatory decisions. Fig. 2 illustrates how the methodologies work in different tiers to facilitate the MPDS.

4.1. Mass-participation clustering

Mass-Participation Clustering is used in MPDS Tier 1 to identify and organize subgroups of participants who have similar preferences or priorities. Its purpose is to cope with the heterogeneity in large stakeholder groups by clustering participants into more cohesive subgroups, each represented by a set of similar opinions. In the MPDS framework, this method comes into play after initial criteria ranking by participants: if a stakeholder group shows widely diverse priority rankings, clustering subdivides the mass of participants into more internally consistent subgroups (Huang, 2023b). This improves representation by ensuring that each distinct viewpoint within a large group is recognized and can be represented in subsequent decision steps. Instead of relying on a single “average” representative for a heterogeneous group (which risks losing minority perspectives), clustering yields multiple representatives, one per cluster, capturing the variety of preferences present.

The role of this method in MPDS Tier 3 is thus to bridge mass inputs and the structured decision phase: it compresses hundreds or thousands of individual inputs into a few representative profiles that can feasibly be invited into deliberation or modeling, without significant loss of information. The methodological foundation of mass-participation clustering lies in unsupervised learning techniques (cluster analysis) adapted to decision preference data. A common approach is to follow the logic of the k-means algorithm, where participants are treated as data points in a preference space. However, rather than Euclidean distance on generic features, the distance metric is tailored to preference information—for example, using a rank correlation measure. In Huang et al (2025a) implementation, a weighted Kendall’s tau distance is computed between participants’ ranked criteria priorities (Shieh, 1998). This distance reflects how similarly two participants order the importance of criteria. Participants are then grouped such that those with more concordant priority rankings fall into the same cluster. The output of the clustering is a partition of the stakeholder group into k clusters (where k may be chosen by the analyst or suggested by validity indices like silhouette coefficient). Each cluster can be characterized by a prototype preference (e.g., the cluster centroid ranking) and is typically assigned a representative participant—for instance, the individual whose preferences are closest to the cluster center. These representatives act as spokespersons or carriers of their cluster’s perspective in later group decision steps. The typical data input to this method is a large matrix of participant preference data (such as criterion rankings or weight distributions from an initial survey), and the output is a smaller set of cluster profiles and recommended representatives. In implementation, practitioners should be mindful of

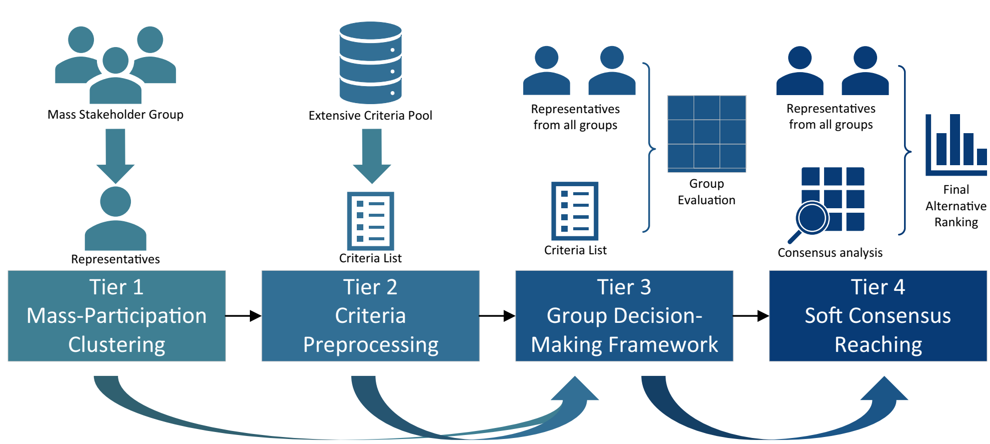

Fig. 2. MPDS pipeline mapping enabling methodologies to the four participation tiers. Tier 1: Mass-Participation Clustering converts broad public inputs into stakeholder subgroups; Tier 2: Criteria Preprocessing distills an extensive pool into a manageable, representative list; Tier 3: a structured Group Decision-Making framework (e.g., MAMCA) engages representatives from all groups for evaluation; Tier 4: Soft Consensus Reaching identifies compromise solutions.

determining a meaningful number of clusters and ensuring clusters are interpretable. Strategies such as incrementally increasing *k* until additional clusters no longer yield substantially new preference patterns (using variance explained or silhouette values) are useful (Kodinariya et al., 2013).

It is also advisable to examine the substantive qualities of each cluster, e.g., which criteria tend to be top-ranked in each group, to validate that they align with recognizable viewpoints or stakeholder segments in the real world. For example, in a large participatory budgeting scenario for urban infrastructure, clustering might reveal distinct groups such as "safety-first" citizens who prioritize public safety criteria and "cost-conscious" citizens who prioritize economic criteria. This clustering technique thus makes large-scale participation actionable by compressing information and ensuring that the subsequent decision analysis (Tier 3) considers all major distinct opinions present in the mass of participants.

4.2. Criteria preprocessing

Criteria Preprocessing in MPDS is a method designed to manage and refine the criteria used for decision evaluation, especially when those criteria are sourced from a large and diverse participant pool (Huang et al., 2023). In mass participation settings, stakeholders may propose a wide variety of evaluation criteria for the decision at hand, leading to an unmanageably long or overlapping list.

The purpose of criteria preprocessing is to select and structure the most relevant criteria before the formal evaluation, ensuring that the criteria set is representative of stakeholder values while remaining cognitively tractable for decision-makers. Within the MPDS framework, this method operates at Tier 2: it takes raw inputs (potential criteria collected from literature, experts, or directly from participant suggestions) and processes them with participant input to yield a finalized criteria list for each stakeholder group. By doing so, it addresses the question: "Which criteria truly matter to the stakeholders, and how can we prune or consolidate the rest?" This preprocessing is crucial in mass-decision contexts because an excessive number of criteria can overwhelm participants and dilute the focus of the evaluation. As guidance from cognitive psychology suggests, decision quality deteriorates when decision-makers must consider too many criteria at once, given the human short-term memory limit of roughly seven (plus or minus two) items (Saaty and Ozdemir, 2003). Thus, an aim is often to end up with a handful of high-priority criteria (commonly 5–9) that collectively capture the essentials of the decision.

The criteria preprocessing method typically follows a three-step procedure. First is Initial Criteria Selection: practitioners or analysts compile an extensive list of potential criteria by drawing from prior studies, best practices, and brainstorming with subject experts or stakeholder representatives. The guiding question is "What factors could distinguish a good and bad alternative for these stakeholders?". This initial criteria pool might be quite long and inclusive. The second step is Criteria Filtering: this is where mass participation can be directly harnessed. Participants (often from the stakeholder group in question) are asked to evaluate the relevance of each candidate criterion. This can be done through surveys where participants mark criteria as relevant or not, and possibly rate their importance or "relevance level" on a scale. By compiling these responses, practitioners can identify which criteria are widely regarded as unimportant (these may be dropped) and which ones are universally or largely deemed relevant. Additionally, criteria that are redundant or highly overlapping can be merged or represented by a broader category at this stage. The filtering step thus narrows the field by removing low-value criteria and combining similar ones. The final step is Final Criteria Selection: using the participant feedback data from filtering, the practitioners apply a selection model to choose a final set of criteria. One effective approach is to apply a Pareto analysis on the relevance scores. In practice, this means identifying the "vital few" criteria that account for most of the importance as indicated by participants (for example, the top 20 % of criteria that cover 80 % of cumulative relevance) (Koch, 2011). Those top-ranked criteria would be kept. The result of this step is a concise list of criteria (often capped around seven items for cognitive manageability) for each stakeholder group. Notably, this framework emphasizes relevance of criteria rather than immediate weighting, weights will be elicited later during evaluation. The preprocessing focuses on which criteria should be considered at all. The output is a cleaned and prioritized criteria set that reflects participant opinions, ready for use in multi-criteria evaluation. From a technical standpoint, criteria preprocessing can involve simple statistical aggregation (e.g., counting how many participants endorsed each criterion) or more complex multi-criteria selection models. Huang et al. (2023) propose a novel selection model that ranks criteria by combining binary relevance votes and graded importance ratings from participants. This model produces an explicit ranking of criteria with minimal ties, helping practitioners decide cut-offs. In sum, Criteria Preprocessing equips MPDS Tier 2 with a systematic filter to handle mass-inputs on criteria, yielding a balanced, representative set of decision criteria for subsequent analysis.

4.3. Structured group decision frameworks

Structured group decision frameworks provide the overarching methodological structure for conducting complex decision-making with multiple stakeholders and criteria. In MPDS, they form the backbone of Tier 3 by defining how the decision problem is framed, how preferences are elicited and aggregated, and how alternatives are evaluated in a group context. Two exemplary frameworks are Social Multi-Criteria Evaluation (SMCE) (Munda, 2004) and Multi-Actor Multi-Criteria Analysis (MAMCA) (Macharis et al., 2012). These approaches share a common foundation in Multi-Criteria Decision Analysis (MCDA) but extend it to explicitly accommodate plurality of stakeholders and viewpoints in a structured way. Their purpose is to ensure that a decision process with many participants remains systematic, transparent, and theoretically sound. In effect, they supply process steps for MPDS, into which the other enabling technologies (like clustering or consensus methods) plug in.

SMCE is a well-established framework geared largely toward public policy decisions (Etxano and Villalba-Eguiluz, 2021). It integrates multiple technical impact dimensions with diverse social perspectives to enable a comprehensive assessment of alternatives. The emphasis in SMCE is on inclusive and transparent evaluation: it combines quantitative data (e.g., indicators of economic, and environmental performance) with qualitative judgments (e.g., stakeholder values, and ethical considerations), and insists on maintaining transparency by keeping criteria expressed in their natural units. In practice, SMCE follows typical MCDA steps: defining objectives, identifying criteria for each objective, scoring alternatives on each criterion, and applying weights. But it does so in a participatory manner. Stakeholders are involved in setting objectives and criteria and in discussing the results. The methodological or technical foundation of SMCE lies in multi-criteria aggregation rules combined with the principle of incommensurability, which acknowledges that not all dimensions can be reduced to a single unit. As a result, SMCE often presents results in multi-dimensional forms (e.g., showing trade-offs without forcing a single composite score) and encourages deliberation informed by these trade-offs. The typical inputs to an SMCE process are a set of policy or project alternatives, a set of evaluation criteria (spanning economic, social, and environmental dimensions), and stakeholder judgments about the importance of criteria or the performance of alternatives. The outputs are rankings or comparative evaluations of the alternatives, along with rich information on conflicts and synergies between criteria and between stakeholder preferences. SMCE has been applied in numerous large-scale contexts, from energy policy assessments to urban sustainability planning (Marta and Giulia, 2020; Munda, 2006; Munda and Russi, 2005). These real-world applications demonstrate SMCE's ability to handle complexity and stakeholder diversity, making it a strong candidate for the structural framework in MPDS Tier 3.

MAMCA, on the other hand, is a specialized MCDA framework explicitly designed to include multiple stakeholder groups in the evaluation of alternatives (Huang et al, 2024a). Developed originally in the transport sector, its distinctive feature is that each stakeholder group can have its own set of criteria and weights for evaluating the alternatives. The methodological steps of MAMCA typically include: (1) problem and alternative definition, (2) stakeholder analysis (identifying stakeholder groups and their objectives), (3) criteria selection for each stakeholder group, (4) evaluation of alternatives by criteria (often using performance indicators and scoring methods), (5) aggregation of results within each stakeholder group (yielding a ranking of alternatives per group), and (6) overall analysis and stakeholder discussion of results. MAMCA's technical foundation is standard MCDA, applied separately for each stakeholder perspective. What it adds is a multi-actor perspective: the outcome is not a single fused result, but a set of parallel results, one for each stakeholder group. These results can be compared to reveal areas of consensus or conflict. This multi-actor view is extremely valuable in mass participation contexts: it highlights where different segments of the public agree on a preferred alternative and where they diverge. For example, MAMCA might show that in a transportation project, the business community's top-ranked option differs from the residents' top-ranked option, indicating a conflict that may need negotiation. By visualizing such comparisons, e.g., via a "dashboard" of group rankings or a graph of alternative scores by group, MAMCA facilitates a structured dialogue among stakeholders (Huang et al, 2020b). Typical inputs to MAMCA include the set of alternatives, stakeholder-specific criteria and weights, and performance data of alternatives on each criterion (Huang, 2023a; Huang et al, 2024b). The outputs are the alternative rankings for each stakeholder group and possibly a composite view to identify potential compromise solutions. In the MPDS framework, MAMCA can play a central role in Tier 3 (the structured evaluation stage), after methods like criteria preprocessing have provided the criteria and methods like clustering have provided representative participants. Empirically, MAMCA has been applied in large-scale projects such as the Oosterweel highway connection project in Belgium and European biofuel strategy assessments, each involving numerous stakeholder groups (government, industry, citizens, NGOs) (Januarius and Macharis, 2010). These cases illustrate that a structured framework like MAMCA can handle real-world complexity, producing a collective outcome that decision-makers could examine to gauge the level of support or opposition across the spectrum.

In summary, structured group decision frameworks such as SMCE and MAMCA provide the necessary scaffolding for MPDS. They ensure that when mass inputs are brought in— many people's criteria preferences, many viewpoints—there is a rigorous process to integrate those inputs. SMCE contributes a philosophy of inclusion and transparency suitable for policy decisions, and MAMCA offers a concrete step-by-step methodology to incorporate multiple stakeholder-specific evaluations in one analysis. Both methods emphasize clarity, stakeholder involvement, and conflict identification, aligning well with the goals of MPDS. They also come with implementation support: for example, dedicated software tools, like the SMCE-oriented tool SOCRATES or the MAMCA Survey Tool, can guide practitioners through the process (Huang et al, 2020b; Munda et al., 2022). Ultimately, these frameworks help turn the mass participation data into organized decision insights, revealing where stakeholders agree, where they differ, and what trade-offs underpin the decision.

4.4. Soft consensus reaching techniques

Soft consensus reaching techniques are employed in MPDS to facilitate convergence toward a final decision or recommendation that a broad base of participants can accept. In large-scale participatory processes, outright unanimity is often unrealistic. Stakeholders have differing values and any chosen alternative may leave some dissatisfied. The aim of soft consensus methods is therefore to achieve a workable level of agreement, or at least non-objection, through iterative adjustment and negotiation, rather than requiring full consensus in the strict sense (Saint and Lawson, 1994). Within the MPDS framework, these techniques come into play at Tier 4, after the alternatives have been evaluated, e.g., via MAMCA/SMCE, and each stakeholder group's position is known. At this stage, the focus shifts from analysis to decision support: helping stakeholders move from their initial preferred alternatives toward a compromise solution if necessary. The "soft" in soft consensus implies flexibility: these methods accept that consensus is a matter of degree and seek to maximize that degree as much as possible. In other words, they measure how close the group is to consensus and try to improve that, rather than demanding all parties fully agree or else the process fails.

A key methodological foundation for soft consensus techniques is the concept of a consensus metric (del Moral et al., 2018). Researchers have developed measures that quantify the level of agreement among decision-makers' preferences on a scale from 0 to 1. Unlike a binary view of consensus such as agree or disagree, soft measures allow for partial agreement. For example, if most participants rank one alternative highly, but a few dissent, the consensus level might be moderate (e.g., 0.6) rather than zero. These measures can be based on distance between preference rankings, statistical dispersion of votes, or fuzzy logic similarity of opinions (DeGroot, 1974; Pyritz et al., 2011). In practical terms, a consensus reaching process often involves: (1) computing the current consensus level, (2) if it's below a desired threshold, identifying sources of disagreement, and (3) suggesting or negotiating adjustments to preferences to improve consensus. For instance, a practitioner might observe that one stakeholder group's strong opposition to the top alternative is the main barrier to consensus; the process would then explore if modifying that alternative or compensating for that stakeholder's concerns could bring them on board. Advanced implementations use optimization models to recommend changes. One notable approach is the inverse problem: instead of asking "given weights, what is the ranking outcome?", we ask "what minimal changes to criteria weights could make a particular alternative become the top choice for all groups?"

Several consensus metrics were developed such as Goers and Horton (2024); Lin et al. (2022); Rodríguez et al. (2018); Tran et al. (2023). Among them, Huang et al (2020a) introduce an inverse Mixed-Integer Linear Programming (MILP) model that seeks a potential consensus alternative by slightly adjusting stakeholder weightings. The idea is to find a compromise alternative that could simultaneously rank first for every stakeholder group, if each group is willing to marginally modify its weighting of criteria. The model provides quantitative guidance: for example, it might output that "Alternative B can become a consensus choice if the environmental group reduces the weight it places on air quality by 10 % and the business group increases the weight on cost by 5 %, etc." Such a result gives practitioners concrete options to discuss with stakeholders. Typical inputs to a consensus technique include the individual or subgroup preference orderings for alternatives and possibly bounds on how much each is willing to compromise on certain criteria or outcomes. The output is usually one or more compromise solutions (alternatives that emerge as broadly acceptable) and/or a set of recommendations for how participants might adjust their positions to increase agreement. These techniques may also provide a running measure of consensus (e.g., "currently the group is at 70 % consensus") to monitor progress. Implementation strategies for consensus reaching often blend computational support with facilitation. On one hand, algorithmic tools (like the MILP model or other consensus support systems) can analyze vast preference data to pinpoint where conflicts lie and suggest resolutions. On the other hand, a human practitioner is typically needed to present these findings and guide stakeholders through discussion and negotiation. One should note that different metrics hold the potential to create better representations for arguing within stakeholder groups, and practitioners should select the metric most appropriate for their decision-making context.

It is important that any suggested compromises are voluntary and transparent (Keisler and Linkov, 2021). Participants should not feel that an outcome is imposed by a black-box algorithm. One effective approach is to use what-if analysis (sensitivity analysis) during stakeholder discussions: e.g., "If group A cared slightly less about criterion X, alternative Y would improve in rank. Is that acceptable?" This engages stakeholders in adjusting their own inputs in pursuit of consensus (Reddy et al., 2019). Another approach, drawn from the literature on fuzzy group decision-making, is to offer recommendations to individuals on how to change their preferences slightly to move closer to consensus (Cabrerizo et al., 2015). For example, a system might privately suggest to an expert that if they downgraded one particular criterion's importance, their opinion would be more in line with the group's, thus increasing consensus. Empirical examples of soft consensus techniques are found in large-scale policy and planning workshops.

More generally, techniques like Delphi surveys, iterative voting, or preference adjustment rounds have long been used to build consensus in large groups (Hasson et al., 2000; Meir, 2017); what MPDS adds is the quantitative rigor and scalability to do this with potentially thousands of participants. As Butler and Rothstein (1991) notes, reaching consensus is about altering individual preferences in a voluntary way to find a mutually preferable outcome. Soft consensus methods provide the tools to identify and encourage those alterations, resulting in decisions that, while perhaps not everyone's ideal, are broadly supported and thus more robust for implementation. In conclusion, soft consensus reaching techniques ensure that MPDS does not stop at analyzing divergent preferences, but goes the final mile to assist in forging a collective decision. They respect that full consensus may be unattainable, yet seek the highest degree of agreement possible. By doing so, they improve the legitimacy and acceptance of decisions derived from mass-participation processes. These techniques complement the analytical stages by addressing the social dynamic of decision-making: helping large groups move from "we agree on the facts, but not on the choice" toward "we can live with this choice." In MPDS Tier 4, this means providing practitioners and stakeholders with systematic guidance to reach a decision outcome that participants feel has emerged from a fair and inclusive process.

5. Case illustration: Brussels construction logistics planning

To demonstrate the MPDS framework in action, we consider a project in the Brussels-Capital Region involving the optimization of construction logistics for a major building site (Brusselaers et al., 2021). This case has been previously examined across multiple studies and publications, each highlighting different methodological or empirical aspects, such as stakeholder engagement processes, criteria elicitation techniques etc. (Brusselaers et al., 2021; Huang et al, 2025a; Huang et al., 2023). However, until now, these contributions have not been systematically integrated within a unifying decision-support architecture. By presenting the MPDS framework retroactively to this case, we aim to harmonize these fragmented analyses into a coherent structure that emphasizes full-cycle stakeholder involvement, multi-criteria rigor, and participatory robustness. The MPDS lens not only allows for a more comprehensive understanding of how stakeholder preferences were elicited, structured, and aggregated, but also serves to reveal how such a process can be adapted under real-world constraints, such as those imposed by the COVID-19 pandemic.

The construction sector is a major generator of urban freight. Recent European studies estimate that construction related traffic can account for $\sim 20-35\ \%$ of all heavy-duty vehicle-kilometers in dense city centers. In Brussels, this challenge is magnified by the city's historical street pattern (narrow, mixed-use corridors), a multi-layered governance structure of 19 municipalities plus a regional mobility authority, and persistently high congestion and air-quality exceedances (Mommens et al., 2019). Against this backdrop, the Brussels-Capital Region launched several pilot projects under the research programmes to test more sustainable Construction Logistics Scenarios (CLS).

One flagship pilot is the City Campus redevelopment in Anderlecht, a mixed-use complex ($\approx$ 31,000 m^2) situated just 3 km from the historic city center and directly abutting residential streets. At peak phase the project was projected to generate 40–60 truck trips per day and up to 200 van movements for subcontractor personnel and small deliveries. The core decision problem therefore centered on selecting a logistics plan that simultaneously minimizes economic cost and on-site delays for the contractor; reduces environmental externalities (local NO_x, $PM_{2.5}$; greenhouse-gas CO_2; construction-traffic noise and vibration); and mitigates societal disruption, notably neighborhood traffic safety, accessibility for local businesses, and overall livability during the build period.

A total of five stakeholder groups were formally recognized for the MPDS process, reflecting the full spectrum of actors that influence, or are influenced by construction logistics decisions:

SG 1 – Construction Site Stakeholders: the project owner/client, developers, and the principal construction contractor. Their objectives span cost, schedule, and on-site feasibility.
SG 2 – Construction-Logistics Providers: third-party logistics firms, consolidation-hub and port operators, and specialist consultants. Their perspective is dominated by operational efficiency and economic viability of transport flows.
SG 3 – Industry Federations & Research Institutes: sector federations and academic or applied-research bodies that advise on best practices and innovation. They provide a sector-wide view with emphasis on economic performance and knowledge transfer.
SG 4 – Public Authorities and Urban-Planning Agencies: municipal mobility departments, regional environment and planning offices, and transport regulators. Their mandate centers on public-interest criteria—traffic safety, emissions, livability, and long-term urban development.
SG 5 – Citizens / Residents (Mass-Participation Group): the broad public living, working, or studying in the neighborhoods surrounding the City Campus. As the mass stakeholder in the MPDS architecture, SG 5 was engaged through a large-scale survey (Tier 1) that collected more than 150 complete responses. Preference data from this survey were subsequently clustered (Tier 2) to reveal distinct resident sub-groups—e.g., noise-sensitive, traffic-flow, environmental. Medoid representatives from each cluster were identified to represent the multi-actor evaluation workshop (Tier 3).

By explicitly recognizing SG 5, the case adheres to MPDS's core idea that mass stakeholders are not an afterthought but a foundational tier. Their aggregated preferences shape criteria weighting, drive the selection of citizen representatives, and ultimately inform the trade-offs evaluated alongside the professional actors (SG 1–SG 4).

In this case study, five logistics configurations were submitted to stakeholders for evaluation. Table 2 summarizes the baseline and the four Construction Logistics Scenarios (CLS), highlighting their core logic and key operational measures.

It should be noted that the fieldwork began just as Belgium entered successive COVID-19 lockdowns. Large in-person workshops were prohibited, which meant the mass-participation citizen group (SG 5) could not join the same Tier 3 deliberation as the professional stakeholders (SG 1-SG 4). To preserve the MPDS logic we therefore operated two parallel but complementary streams of work. The normal stakeholder dialogue and the mass-participation survey stream advanced in parallel, converging only after both datasets were complete. The approach retained the four-tier MPDS architecture while adhering to public health restrictions.

Table 2
Baseline and construction logistics scenarios (CLS) evaluated in the Brussels case.

Code	Name	Core Logic and Key Measures
BAU	Business-as-Usual	Decentralized, contractor-led logistics; many small, diesel truck/van trips; no special scheduling or consolidation.
CLS1	Construction Planning & JIT	Central logistics schedule; just-in-time deliveries; shared timetable and access management on-site; priority to nearby suppliers for bulky goods.
CLS2	Consolidation Center (CCC)	Off-site hub (water/rail accessible) to bundle flows; long-haul by barge/rail, last-mile by fuller trucks; possible multi-hub network.
CLS3	Preferred Road Network	Designated corridors/time windows for construction traffic; enforcement of route compliance; avoids sensitive zones/peaks.
CLS4	Electric Vehicles (Zero-Emission)	Progressive switch to electric mixer trucks and other EVs; dedicated charging hub; trip bundling and slotting to maximize range.

5.1. Conventional stakeholder group track SG 1 - 4

Experts and institutional actors from SG 1 to SG 4 progressed through the usual Tier 1 information obtaining, Tier 2 modeling and a Tier 3 multi-actor workshop, but in hybrid web-conference mode. Throughout these sessions the MAMCA web dashboard provided real-time transparency, allowing participants to view criteria weights, scenario scores, and trade-offs despite the dispersed format.

Tier 1 focuses on gathering information from stakeholders about what criteria matter to them. At this stage, practitioners identify and consult all relevant stakeholder groups (e.g., government, industry, community, etc.). Through surveys, stakeholders share their objectives, concerns, and preferences regarding the decision context. These inputs are then translated into a tentative long list of potential criteria. The idea is to capture everything stakeholders find important. For example, a transport company might emphasize cost and delivery time, while residents might raise air quality or noise as criteria. This brainstorming is often informed by stakeholder consultation and literature, ensuring no major aspect is overlooked. The result of Tier 1 is a comprehensive collection of raw criteria candidates drawn directly from stakeholder insights. Importantly, in this study we opted for MAMCA framework, where each stakeholder group could later focus on the criteria relevant to their interests. Thus, the Tier 1 list may include a wide variety of criteria, some of which pertain more to one group than another. The goal is to be inclusive at this stage. For instance, if five stakeholder groups are involved, their combined input might yield dozens of criteria. This long list serves as the foundation for the next tier, where it will be distilled into a workable evaluation set.

In Tier 2, the broad list of criteria is refined into a final set through expert consultation and collaborative discussion. This step often involves domain experts, practitioners, and sometimes key stakeholder representatives. They review the Tier 1 long list to merge overlapping items, eliminate or rephrase ambiguous ones, and ensure each criterion is relevant and measurable. The aim is to define a concise yet comprehensive set of criteria for each stakeholder group's evaluation. In practice, Tier 2 can be seen as a co-design process with experts (Stelzle et al., 2017): using the stakeholders' raw input as a starting point, the group agrees on which criteria will ultimately be used. Table 3 presents the final criteria list.

A half-day web workshop brought together the same SG 1–SG 4 representatives. Using the MAMCA software, participants first applied a Modified Simos procedure to assign weights to their chosen criteria (Huang et al, 2025b, 2020b). Next, facilitated break-out sessions reviewed factual performance scores for the five alternatives (BAU plus CLS 1–4). Participants then rated each alternative on each of their criteria; the software immediately produced individual and group rankings.

The results highlight an overall preference for the Construction Consolidation Center (CLS 2). In contrast, site owner, developer, and main contractor (SG 1) ranked CLS 2 markedly lower, citing additional handling costs and perceived damage risks from double trans-shipment. The hybrid workshop closed with a synthesized view showing where groups converged (strong support for CCC on environmental and traffic-reduction criteria) and where they diverged (cost sensitivity of SG 1). The detailed results can be found in Brusselaers et al. (2021). These results, together with the mass-participation citizen analysis, were forwarded to Tier 4 decision-makers for final reconciliation.

5.2. Mass-participation track (SG 5 — citizens)

In Tier 1, following an expert-led construction of the global long list of candidate criteria, a dual-channel survey (online and postal) was distributed to households in the impacted area. Residents were simply asked which of the listed impacts they regarded as relevant to the project. The valid responses provided a frequency score for every criterion, serving as the raw, citizen-driven salience measure. In Tier 2, we then applied the formal criteria-preprocessing routine of Huang et al. (2023), ranked the long-list items by the proportion of citizens who flagged them, and assessed coverage across the economic, environmental, and societal pillars. The algorithm retained the nine most salient criteria for SG 5, well within the 7±2 cognitive guideline, thereby balancing representativeness and survey burden. Then we returned to Tier 1, where a second round of questionnaires asked citizens to rank those nine criteria in order of personal importance. Each respondent's ranking was converted to a weight vector and used as input to a K-medoids clustering (rank-distance metric) (Huang et al, 2025a). This produced four internally homogeneous subgroups that together explained over 85 % of variance in citizen priorities. For each cluster, a medoid respondent was identified as the archetypal weight profile.

Because the citizen stream lagged behind the professional workshop by almost two years, live participation in Tier 3 was infeasible. Instead, domain experts role-played the four medoid profiles during a dedicated MCDA session: the weights were imported directly from the survey, and the experts scored each alternative on the nine citizen criteria using the same evidence base provided to SG 1–SG 4. This preserved the structural equivalence of the evaluation even though residents were not physically present. Across all four citizen clusters, the scenario "Electric Concrete Trucks" (CLS 4) emerged as the top-ranked alternative on eight of the nine criteria, reflecting strong public support for zero-emission construction logistics.

After the citizens' preferences had been processed, a multi-actor view was then generated under MAMCA evaluation framework. A side-by-side comparison of each stakeholder group's ranking for all five alternatives is illustrated in Fig. 3. This visual synopsis makes trade-offs transparent: decision-makers can immediately see where preferences align, where they diverge, and how strongly each group supports or opposes a given scenario.

5.3. Post-hoc consensus exploration (Tier 4)

Because the pandemic prevented a live Tier 4 deliberation, we carried out an ex-postconsensus exploration using the consensus reaching model of Huang et al (2020a). The model asks: "How much would each stakeholder group's criterion weights have to shift for a given alternative to become the joint top choice?" By incrementally and proportionally

Table 3
Evaluation criteria (with codes g_1–g_{23}) grouped by sustainability pillar.

Category	Criterion (code)	Operational definition / Typical indicator
Economic	g_1 Enforcement costs	Additional public/contractor costs to monitor and enforce logistics rules (routes, time windows).
	g_2 Viability of investment	Financial feasibility/return of measures (CCC, EV fleet) over the project horizon.
	g_3 Profitable operations	Ability of logistics providers to operate without losses under the scenario.
	g_4 Transportation costs	Direct costs of moving materials/personnel (€/ton-km, €/trip).
	g_5 Adaptation costs	Costs borne by third parties due to detours, parking loss, business disruption.
	g_6 Impact on transport infrastructure	Congestion, road wear or blockage attributable to construction traffic.
	g_7 Delivery quality / reliability	Timeliness, completeness and damage-free delivery rates to site.
Environmental	g_8 Air pollution	Local pollutant emissions (NO_x, $PM_{2.5/10}$) from logistics traffic.
	g_9 Climate change	Greenhouse-gas emissions (CO_2-eq) from transport/equipment.
	g_{10} Noise pollution	Noise levels and exposure duration from construction vehicles/operations.
	g_{11} Vibration	Ground vibration impacts on nearby buildings/residents.
	g_{12} Water pollution	Risk of spills/runoff or contamination linked to logistics activities.
	g_{13} Biodiversity impact	Disturbance or habitat loss in/around corridors or site.
	g_{14} Landscape / visual quality	Temporary visual intrusion or clutter from hubs, staging areas, vehicle queues.
Societal	g_{15} Labour conditions	Health, safety and fairness for workers in logistics operations.
	g_{16} Social / political acceptance	Degree to which citizens/businesses accept the logistics plan and rules.
	g_{17} Business climate during works	Ability of local firms to remain accessible/profitable during construction.
	g_{18} Area attractiveness / livability	Perceived quality of life for residents/visitors during project period.
	g_{19} Socio-economic revitalisation	Longer-term benefits post-construction (improved accessibility/services).
	g_{20} Security of materials	Theft/loss risk for materials in transit or at hubs/sites.
	g_{21} Traffic safety impacts	Accident risk for vulnerable users and general traffic due to construction flows.
	g_{22} Accessibility (people/goods)	Ease of reaching the area and delivering goods during the works.
	g_{23} Diverted traffic	Extent and impact of rerouted traffic on alternative streets/areas.

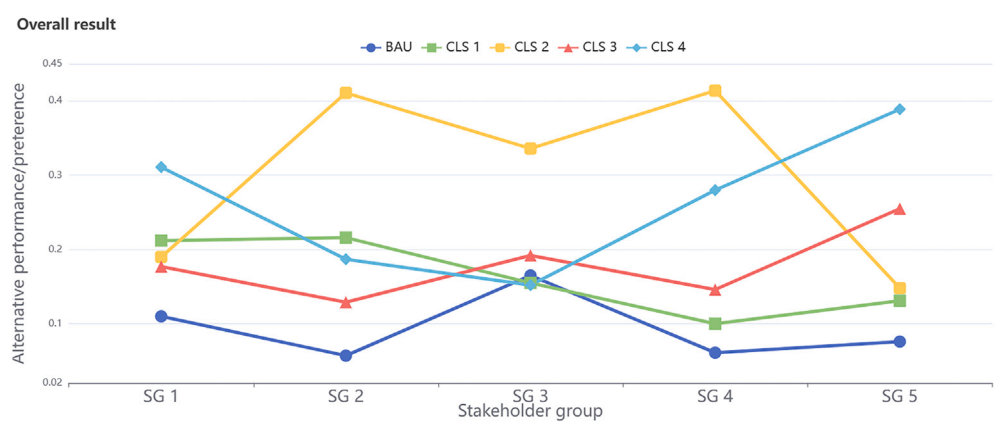

Fig. 3. Multi-actor view produced by the MAMCA software (Huang et al, 2025b). Columns correspond to stakeholder groups (SG 1–SG 5); rows list the five alternatives (Brusselaers et al., 2021; Huang et al, 2025a).

modifying the original weight vectors, the procedure records two quantities for every scenario. The total modification records the aggregated absolute change applied across all groups' weights; and the total rank records the summed ranking position of the scenario once the modified weights are applied (a lower value indicates greater collective preference). The result of the consensus-reaching analysis is presented in Fig. 4.

Plotting total rank against total modification produces a Pareto frontier. Points closer to the origin require smaller weight adjustments to achieve a better aggregate rank and are therefore interpreted as easier compromise solutions. The result reveals CLS 2 attains a collectively favorable ranking with the smallest aggregate change to stakeholder weights, signaling the least resistance path to consensus. The Electric Vehicle scenario (CLS 4) sits next closest to the origin, indicating that electrification is the second-most viable compromise once modest reweighting is allowed. Conversely, the Business-as-Usual baseline (BAU) remains distant from the frontier even after substantial weight perturbations, underscoring its poor fit with aggregated stakeholder preferences. We recomputed the alternative scores using the modified weight vectors identified by the consensus-reaching procedure. As summarized in

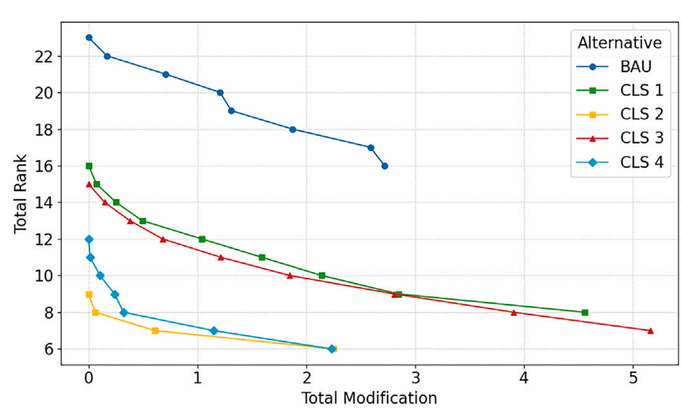

Fig. 4. Consensus-search frontier: each curve traces how an alternative's aggregate rank improves as incremental weight modifications are applied. Scenarios nearest the lower-left corner (smallest modification, lowest total rank) represent the most attainable consensus options (Huang et al, 2020a).

Table 4, this adjustment yields CLS 2 as the closest-to-consensus option. In particular, for SG 1 the modified weights produce a complete tie across alternatives (each at 0.200), which removes opposition and makes CLS 2 a (weak) top choice; SG 2 and SG 3 continue to rank CLS 2 first; SG 4 also retains CLS 2 in the top position; and SG 5 elevates CLS 2 to second place, surpassing CLS 3, which was originally its second choice. Under the minimal weight modifications considered, this is the best attainable compromise configuration: CLS 2 is (weakly) first for SG 1, strictly first for SG 2–SG 4, and second for SG 5. Although the analysis is numerical rather than deliberative, it provides Tier 4 decision-makers with a transparent, quantitative map of where consensus is most readily achievable.

6. Discussion

The case study highlights the remarkable adaptability of the MPDS framework in accommodating broad and continuous stakeholder participation. Unlike rigid one-off consultation approaches, MPDS is designed as a multi-phase, adaptive process that can involve a large number of stakeholders at different stages of decision-making. This flexibility means that when a stakeholder group is very heterogeneous (with diverse priorities), MPDS can include more participants throughout the process to ensure no important perspectives are lost. In practice, the framework allowed additional participants to be engaged whenever needed, for example, by expanding input collection or analysis steps. It thereby increases the level of representation without overwhelming the process. The result is a more inclusive and robust decision procedure that minimizes the information loss and biases that might occur if only a few representatives were involved. Such adaptability is crucial in complex, real-world projects where stakeholder views can evolve or unexpected issues arise, and it underscores that MPDS is not a fixed sequence of steps but a responsive framework tailored to stakeholder needs.

A central finding in this case is the importance of stakeholder involvement from beginning to end of the project. In MPDS, stakeholders are not merely consulted at a single point; instead, they actively participate in defining the problem, shaping criteria, evaluating options, and final decision-making. For instance, early in the process stakeholders (or a subset of them) helped define or refine the criteria that reflect what matters to each group. Then a large number of participants from each group were engaged via an online survey to rank these criteria by importance. This ensured that even at the problem-structuring and criteria-setting stage, stakeholder voices were heard. Subsequently, the framework's design called for workshops with stakeholder representatives to perform a detailed evaluation of the alternatives. During these workshops, participants elicited criteria weights together and assessed the performance of each alternative, bringing in local knowledge and preferences. Finally, the stakeholder representatives discussed the results and worked toward a consensus on the preferred solution. In other words, stakeholders were meaningfully involved at every phase: from defining objectives and criteria, through analyzing options, to deciding on the outcome. This continuous involvement goes well beyond traditional consultation; it is a form of co-design and co-creation where stakeholders contribute both their preferences and their ideas for solutions. The case study thus illustrates how MPDS operationalizes the idea that those affected by a decision should be engaged throughout the process, not just at the end when options are already fixed. This approach ensured that the final decision (such as the choice of logistics solution in the construction project) was grounded in stakeholder input at every step, increasing its relevance and acceptance. Engaging stakeholders so deeply and early-on has significant theoretical and practical benefits.

One key benefit is enhanced procedural justice. Procedural justice concerns the perceived fairness of the decision-making process, essentially, how decisions are made and who is involved in making them (Chan Kim and Mauborgne, 1998). By involving stakeholders from the outset and giving them real influence over criteria and alternatives, the MPDS framework aligns with procedural justice principles. Stakeholders can see that the process is transparent and that their voices are genuinely considered in shaping outcomes. In the case study, this was evident as local residents and other stakeholders had a say in defining evaluation criteria and could trace how their input affected the final recommendation. This approach is consistent with the MPDS participation pyramid, which stresses that even when not all stakeholders are present in final-stage deliberation, they are informed, consulted, or considered from the start. Such inclusivity addresses the normative expectation that people should have a say in decisions that affect them, thereby boosting the legitimacy of both the process and its outcomes. When stakeholders feel the process is fair, they are more likely to view the outcome as legitimate and acceptable, even if it may not be everyone's first choice. The MPDS framework's insistence on beginning-to-end involvement thus embodies a fair process ethos: it distributes decision-making power more evenly rather than concentrating it in the hands of a few experts or officials. This is crucial in complex policy settings (like urban construction logistics) where multiple parties have valid but differing concerns.

Another benefit of MPDS's approach is the promotion of high deliberative quality in stakeholder discussions. Because stakeholders are continuously engaged and well-informed by each step, the eventual deliberations tend to be richer and more constructive. During the workshop stage of the case, the selected stakeholder representatives arrived armed with knowledge of the criteria rankings (from the survey) and an understanding that there were diverse viewpoints within the community. The framework fostered an environment of mutual respect and reason-giving: participants were encouraged to explain their perspectives and listen to others in order to reach a consensus. Stakeholders could scrutinize evidence together and debate trade-offs in an informed manner. The quality of information available to participants was high. They had the survey data showing community preferences, and technical data on alternative impacts, which further improved deliberation. In essence, MPDS created a mini public deliberative forum within the project, where diverse stakeholders engaged in reasoned discussion guided by the shared goal of solving a local problem. The communication was characterized by mutual respect and an openness to compromise, which literature identifies as hallmarks of successful deliberative processes. This contributed not only to better collective decisions but also to a sense of joint ownership of the outcomes.

Table 4
Alternative scores by stakeholder group under baseline (original) vs. consensus-adjusted (modified) weight vectors. Rows sum to 1.0; larger values indicate greater preferences for the alternative within the group.

	Baseline (original weights)					Consensus-adjusted (modified weights)				
	BAU	CLS 1	CLS 2	CLS 3	CLS 4	BAU	CLS 1	CLS 2	CLS 3	CLS 4
SG 1	0.110	0.212	0.190	0.177	0.311	0.200	0.200	0.200	0.200	0.200
SG 2	0.057	0.216	0.411	0.129	0.187	0.057	0.216	0.411	0.129	0.187
SG 3	0.165	0.155	0.336	0.192	0.152	0.165	0.155	0.336	0.192	0.152
SG 4	0.061	0.100	0.414	0.146	0.280	0.061	0.100	0.414	0.146	0.280
SG 5	0.076	0.131	0.148	0.255	0.389	0.085	0.119	0.165	0.151	0.481

Crucially, the MPDS framework also facilitates learning throughout the process both for stakeholders and for decision-makers. Because stakeholders participate in multiple stages, they undergo a kind of iterative learning or "social learning" experience. Each stage exposes them to new information and to the perspectives of others, prompting reflection and adaptation. For example, when community members saw in the survey results that there were distinct preference clusters, they learned that their community is not monolithic and that different people value different outcomes. Later, during the workshops, stakeholders directly engaged with others who held different priorities, which often led to greater understanding and empathy. This case confirms what participatory decision theorists suggest: multi-actor processes create a learning loop for stakeholders. Through facilitated activities, participants gradually learn to view the decision problem in a broader, more informed way. In the MPDS workshop, for instance, a resident primarily concerned with traffic might have learned from others about the health impacts of air pollution, while those focused on air quality learned about feasibility constraints on certain alternatives. Such exchanges can shift individual mindsets from fixed positions toward a more integrative outlook. This process is analogous to what Argyris (2002) describe as "double-loop learning," where participants don't just adjust their preferences within given criteria, but can even reconsider the underlying criteria or objectives in light of new insights. Indeed, the MPDS case showed stakeholders becoming more prone to search for common solutions rather than stick to siloed positions. By the end, many stakeholders converged on supporting the electric concrete trucks alternative, a choice that balanced several criteria (noise, air quality, accessibility) and was perhaps not obvious to everyone at the start. Their convergence was aided by the learning that occurred: as each participant understood the trade-offs and others' reasoning, the group moved toward a shared preference. From the project team's perspective, this stakeholder learning is invaluable, as it builds capacity and trust. Stakeholders leave the process better informed about the issue at hand and about the complexities of decision-making. They also gain experience in participatory governance, which can translate into more constructive engagement in future projects. In summary, MPDS serves not only to inform the decision but also to educate and empower stakeholders, transforming the exercise into a two-way learning experience (stakeholders learn about policy impacts and trade-offs, while project planners learn about stakeholder values and local knowledge).

Finally, the case study underlines how the flexibility of MPDS helped it adapt to practical challenges such as the COVID-19 pandemic and stakeholder availability constraints. In this case, the COVID-19 outbreak occurred during the project timeline, which posed a serious challenge to traditional face-to-face engagement. Lockdowns and social distancing rules meant that in-person workshops or meetings could not be held as originally planned. Many participatory initiatives stalled during the pandemic, but the MPDS framework was able to weather this disruption. Its multi-modal design (combining online surveys with smaller in-person or virtual workshops) provided a built-in resilience. Although moving the workshop online required some adjustments (and inevitably lost a bit of the social nuance of face-to-face discussion), it ensured the continuity of the process. The flexibility of MPDS is evident in how it accommodated this shift: the framework's emphasis on clear, stepwise communication meant that participants had received materials (like survey results and alternative information) beforehand, making the virtual discussion more focused. Moreover, because MPDS already had a distributed engagement model (many people contributing individually through the survey, then a subset deliberating), it was relatively straightforward to split activities across online platforms. The combination of asynchronous and synchronous engagement provided multiple avenues for participation, accommodating people's different schedules and constraints. This multi-channel engagement is a practical strength of the framework. By being flexible in methods and timing, the framework ensured that the process remained inclusive under real-world conditions. In the face of unexpected delays, MPDS demonstrated resilience. The team was able to pause and resume activities without losing the thread of stakeholder input, because each phase produced tangible outputs that could be archived and reintroduced to participants after delays. This adaptability is a vital practical attribute even under crises like COVID-19, the participatory process can continue meaningfully.

7. Limitations and potential solutions

As with any structured participation framework, MPDS entails trade-offs between analytic rigor, inclusiveness, and feasibility. The following remarks delineate the principal limitations encountered in practice and outline pragmatic ways to mitigate them, so that prospective adopters can judge where the approach is most appropriate and how to deploy it effectively.

A first limitation is the time- and resource-intensive nature of the full MPDS cycle. By design, the process spans 4 tiers, where each stage demands facilitation, communication, and analysis, which can strain limited budgets and calendars, especially in settings with tight decision windows or dispersed stakeholders. The practical implication is that end-to-end execution may be challenging for routine or urgent operational choices. MPDS is therefore best suited to high-stakes, multi-criteria decisions where legitimacy and implementation risks are salient, e.g., urban mobility and land-use plans, infrastructure logistics and siting, environmental and climate policy portfolios, and similar contexts in which early investment in participation reduces downstream resistance, appeals, and rework. Where constraints bind, a modular "MPDS-lite" configuration can preserve the method's logic while managing duration: citizen elicitation and expert modeling can proceed in parallel; previously validated artifacts like criteria lists can be reused to compress setup time. When convening a full workshop is infeasible, role-playing medoid profiles from citizen clusters offers a transparent proxy for deliberation, provided the procedure and its limits are documented and followed by a post hoc validation step.

A second limitation concerns vulnerabilities in the information and feedback chain that connects the tiers. MPDS relies on a traceable bottom-up flow: mass inputs inform criteria, criteria and evidence inform representative evaluations. And an equally deliberate top-down flow—decisions and rationales are communicated back to all contributors. Breaks in either direction have distinct consequences. If outreach is poorly designed or weakly publicized, Tier 1 can suffer from non-response bias and under-representation; if Tier 2 lacks clear documentation of screening and synthesis choices, criteria mis-specification can propagate through the model; if Tier 3 representatives are ad hoc or under-briefed, weights and scores may be noisy or inconsistent; and if Tier 4 does not explicitly report how inputs shaped the decision, stakeholders may infer tokenism. The risks are validity (biased rankings), legitimacy (erosion of trust), and implementation (policy resistance when overlooked concerns surface late).

These risks can be contained through disciplined process controls that do not add undue complexity. Minimum disclosure standards established at the outset—e.g., plain-language briefs on objectives, alternatives, data sources, and modeling assumptions, updated when changes occur—support informed participation and auditability. Traceability can be engineered into the pipeline by preserving a documented chain from Tier 1 signals to Tier 2 criteria, from Tier 3 weights and scores to Tier 4 conclusions, with versioned datasets and decision logs. When participation is partial or delayed, analytical backstops can bound uncertainty and make limitations explicit: sensitivity and robustness analyses that report how rankings vary under plausible weight perturbations, and consensus-frontier diagnostics that indicate which alternatives approach compromise with minimal adjustments. Finally, closing the loop with a concise "evidence-of-use" report, which maps each group's input to criteria choices, evaluations, and the adopted solution to help sustain trust even among stakeholders who did not obtain their first-best outcome.

In sum, MPDS delivers the most value where legitimacy, distributional impacts, and multi-criteria trade-offs are central, and where organizations can commit to a transparent, staged process. Its limitations are real but manageable in practice. At the same time, we acknowledge that these mitigations are only partial. Future work should be developed to convert the current set of pragmatic fixes into a cumulative, evidence-based toolkit, progressively extending MPDS's feasibility while preserving its core commitment to inclusive and credible decision support.

8. Conclusion

This paper has systematically presented the Mass-Participation Decision Support (MPDS) framework, aiming to fill a critical gap in the decision sciences regarding large-scale stakeholder inclusion. The contributions of MPDS can be summarized as follows:

- Conceptual Innovation: MPDS formally introduces the "mass-participation" paradigm into decision support, asserting that inclusiveness is not just a feel-good add-on but a foundational element of legitimate and sustainable decision-making. It reframes decision support to explicitly account for the voices of very large stakeholder groups that have traditionally been marginalized or treated as passive consultees.
- Structured, Tiered Framework: We propose a clear role-based architecture for participation, with differentiated levels (Information, Consultation, Collaboration, Empowerment). This ensures that stakeholders engage at a level commensurate with their capacity and role. Crucially, even the broad public is guaranteed basic rights in the process—the right to be informed and the right to a voice are built into the first tier of MPDS. Likewise, the top-tier decision makers operate with the understanding that they must justify their choices in light of the inputs from all other tiers, promoting accountability.
- Systemic Integration: MPDS stresses the integration of information flows from the bottom up. Unlike fragmented approaches where public opinion might be collected but then ignored, MPDS structurally ties the outcome of each phase to the next. The framework's design means early-stage stakeholder inputs directly shape the alternatives considered and influence criteria weighting through to the final decision. This creates an analytical through-line from stakeholder values to decision outcomes, enhancing transparency and trust in the process.
- Decision-Making as Social Learning: Beyond producing a decision, MPDS facilitates a social learning process. Stakeholders at all levels gain a deeper understanding of the decision's complexity, the trade-offs involved, and the perspectives of others. For instance, citizens learn why certain technical measures are needed, and experts learn to appreciate on-the-ground concerns. This mutual learning can foster empathy and reduce resistance when the decision is implemented. In the long run, such processes can build capacity for communities to handle future decisions in a more cooperative manner, thereby improving the overall governance and management of public issues.
- Technical Empowerment: We have shown that MPDS is operationalizable thanks to modern decision-support techniques. Tools like clustering algorithms for preference segmentation, formal criteria selection models, multi-actor evaluation software, and consensus measures each tackle specific challenges. By leveraging these, MPDS is not just a theoretical ideal but a practical approach that can be executed even in large-scale settings. Our discussion of the Brussels case and related research demonstrates that these techniques indeed work in field applications.

Moving forward, further research is needed to refine MPDS and extend its applicability. First, the theoretical foundation can be enriched by drawing from fields like deliberative democracy (to better measure the quality of participation) and behavioral decision science (to understand how large groups articulate preferences). Second, a richer toolbox of techniques should be explored. For example, digital participation platforms could be integrated at Tier 1 to broaden reach and feedback, and AI-assisted analysis could help synthesize qualitative inputs or open comments from thousands of participants. Third, MPDS should be tested and validated in a variety of decision domains: environmental planning, urban development, budgeting processes, healthcare policy, and beyond. Each domain has its nuances, and iterative trials will help generalize the framework and identify any limitations.

In conclusion, MPDS represents an important step in the development of decision support toward more inclusive, learning-oriented, and legitimate practices. By systematically enabling mass participation, we move closer to the democratic ideal of decisions "with the people, by the people, for the people," while still harnessing the benefits of expert knowledge and structured analysis.

Declaration of competing interest

The author declares that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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