

Beyond the Triplet: Risk as Social and Political

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Abstract: Risk analysis, as practiced in engineering, is a political endeavor. Engineering advancements are driven by the need to solve societal problems with technology and are beholden to technical and non-technical requirements. The political scope of engineering has been well-studied; here, we argue that risk, as a subset of engineering, includes similar political constructs. Because of this, the concept of risk extends well beyond quantifiable hazards and event probabilities. Recognizing the political nature of risk enables the inclusion of non-scientific and non-quantifiable characteristics alongside the traditional elements of technical risk analysis. This shift in perspective can produce risk assessments that are more capable of handling societal and existential risk scenarios, more responsive to risk as perceived by stakeholders, and reinforce the inherently unquantifiable social duties of engineers and scientists. This paper reviews the political and social realities of risk in an engineering context; we argue for the broader inclusion of extra-scientific values in risk assessments and look to the assessment of existential risks as a principal application for this broadened paradigm of risk assessment.

1. INTRODUCTION

Engineering, as the realization of new technologies and techniques, being a political practice is not a novel concept. The artifacts of engineering, along with its systems of organization and operation, such as the economy and technology, have been recognized as political since at least the latter half of the 19th century [1]. Critiques of the economy as non-political is a recognition that any domain or activity in which humans have a deciding role is, to some degree, political [2, pp. 4–5]. This critique has similarly been applied to engineering artifacts and practice [3], [4]. “Political” in this sense is not in reference to the beliefs or persuasions of engineers, but to the reflexive relationship between engineering practice and the social realm: the fact that social concerns dictate engineering decisions and vice-versa. Beyond its practice, engineering produces artifacts that both shape and are shaped by social dynamics. Concepts like technologically enhanced capitalism ([5], [6]) show how technology can reinforce existing power structures [7]. At the same time, social pressures actively influence the design, form, and function of technologies – like social media [8], [9].

Here we will argue that engineering risk – the expected severity of some unwanted event ([10]) – is also a political construct; thus, risk analysis is a political practice and demands *reflection* and critique. It is paramount that engineers and risk analysts recognize the ways in which they have a significant impact – not only on their system, but on their organization, communities, politics and society at large. This requires that engineers fully understand how implicit social and political judgements shape their practice. Embracing these foundational aspects of practice empowers new strategies that can produce an engineering discipline that better serves the public interest, and risk assessments that are respondent to real societal concerns. This is a critical reframing that is necessary to truly understand risk assessment as an engineering practice with significant societal consequences beyond the system of interest.

Framing risk analysis as inherently political is not new, though it has more often emerged from political philosophy or science and technology studies than from risk science [11], [12], [13]. This political lens

is evident in ongoing debates about whether and how to incorporate public participation in risk assessment. The contrast between paternalist and participatory approaches ([14]), for example, reflect shifting views on how social concerns should be accounted for in evaluating risk. Similarly, the existence of various risk acceptance criteria ([15]) and competing theories of risk perception ([14], [16]) suggest that risk is not *purely* scientific, but also shaped by experiential, personal, and political factors. Recognizing this, scholars have identified the societal implications of risk assessment and the need for critical reflection from engineers [17], [18].

This paper makes the argument that risk, as an entity rife with social and political considerations, extends beyond the confines of strict science. As a result, risk assessment requires engineering expertise *and* deliberate commitment to questioning beyond just technical safety. While this paper uses artificial intelligence (AI) as an illustrative context for the political realities of risk, the arguments are broadly applicable to most, if not all, “risky” systems.

The remainder of this paper is structured to provide a thorough discussion of risk as a political practice, beginning with a review of risk and its interaction with social considerations in Section 2. Section 3 builds on this with an exploration of the roles of hazard and probability as elements of risk analysis, and the role of risk in decision-making. Section 4 explores why the effective practice of risk analysis – the fulfillment of its social mission – necessitates going beyond the traditional risk triplet, and how that may be done. Section 5 expands on the implications of an expanded risk analysis for engineering as a discipline, and Section 6 concludes with a summary of the work and its impact.

2. RISK AND SOCIETY

Risk is a well-studied subject with various definitions depending on application and domain. This paper focuses on engineering risk, which is generally defined using the risk triplet ([22]) that provides a good balance between explanatory power and quantitative concision. However, here we will argue that the risk triplet is inadequate for meeting the social mission of risk assessment as a political venture.

2.1. Risk, Analysis, and Perception

Engineering risk is generally treated as a function of the scenario, its probability, and the consequences if realized. These constructs map nicely onto a set of concise questions defining risk, known as the “risk triplet” [22]: *what can go wrong?; what is the likelihood of that happening?; and what are the consequences if that happens?* The risk triplet is the foundation of quantitative risk analysis – the “gold standard” of risk assessment in engineering. Critically for the process of risk management, the risk triplet allows for the distillation of system risks into a single value (the “risk value” of a system) and facilitates the prioritization of risks and comparison of options. However, this “risk distillate” masks factors that are important in decision-making, such as the distinction between high-probability, low-consequence and low-probability, high-consequence risk events. These distinctions impact tangible engineering considerations, like the assessment of insurance, and more subtle considerations like public perception [23]. This shortcoming of the “risk distillate” approach is well understood and is the basis for risk communication devices like Farmers curves and risk matrices [24].

However, the shortcomings of extant approaches to risk assessment are not limited to the distillation of a single value – there are real issues with the risk triplet itself. Namely, the risk triplet incorporates a limited number of factors important to understanding – and fairly/justly mitigating – risk, and it implies that consequences can be reliably enumerated and quantified. Its widespread adoption has also led to the prioritization of quantitative risk analysis over qualitative assessments, which contributes to these issues. Broadly speaking, the practice of risk assessment does not align with the perception of risk and thus does not actually respond to the fears and concerns of users and other stakeholders.

It is often claimed that the public are poor judges of risk, with major discrepancies between perceived risk and the “real” values obtained by formal risk assessment [15], [25]. This insight is gleaned from the psychometric theory of risk perception, which identifies the largely value-laden factors used by non-

experts in their perception of risk: the “dread” nature and distribution of consequences, the sense of agency in the activity, and sense of agency in decisions among others [16]. The factors that shape how people understand risk thus fundamentally differ from those used to calculate it as an engineering construct. Further, risk perception appears relatively insensitive to the actual probability or size of consequences, unless those factors are more memorable (availability bias) [26]. Because the perception of risk is so reliant on value-laden, unquantifiable characteristics, some champion risk assessment as a scientific and unbiased method to protect the public from engineering risks [14], [27], although others have argued that the conservative nature and technical requirements of risk assessment may act to contravene public good-oriented innovation [28].

2.2. Risk Assessment as a Social Mission

What is the purpose of risk assessment? Ideally – or idealistically – risk assessment is meant to ensure that the public is safe from harm due to engineered systems. As engineers with a duty to safeguard the safety, health and welfare of the public ([20]), risk assessment should be the means by which we determine when actions and decisions present danger. As non-experts, users of technology and systems – the general public and other “stakeholders” – trust scientists and engineers to keep them safe from various harms. That trust – implicit or explicit – is forged through the public’s experiences with the technology and by risk communication from the experts. Since its introduction, risk assessment has grown into a fully-fledged discipline largely focused on risk reduction in public-facing systems like commercial aviation, oil and gas operations, and nuclear power. As a discipline, risk assessment intends to protect the public, largely incapable of formally assessing risk in the same manner, from harm [28].

Practically, however, the assessment of risk is often undertaken as a sort of optimization problem or simple compliance task. Consider, for example, situations wherein the consequences – both type and magnitude – are highly uncertain and/or not immediately legible (e.g., artificial intelligence and other long-term societal risks). In such circumstances, rather than serving as an unbiased means through which to determine a proper course of action, risk assessment may actually serve to help promote system development despite the potential for harm. As Winner (2020) argues, the designation of something as a “risk” (rather than, e.g., a hazard or danger) is the prerequisite to lengthy analyses that may leave the hazard in place, as the burden of proof falls to the claim of unacceptable risk. This asymmetry favors the industry rather than the public good. At the same time, the term “risk” implies a willingness-to-accept that may be unwarranted or non-existent, and invites lengthy analyses that can preserve the status quo as the burden shifts to the proof of safety rather than the demonstration of possible harm [28]. At the same time, the term “risk” implies a willingness-to-accept that may be unwarranted or non-existent, and invites lengthy analyses that can preserve the status quo as the burden shifts to the proof of safety rather than the demonstration of possible harm.

In a sense, it seems that risk assessment – at least in many applications – has strayed from its intended mission of public safety. This separation between ideal and realized practice is a natural consequence of multiple factors, including the development of sophisticated quantitative approaches to risk assessment. While methods such as probabilistic risk assessment (PRA) have undoubtedly aided in developing safer systems, they prioritize quantifiable system characteristics to the exclusion of critical, but qualitative or intangible considerations. With the push for PRA and quantification generally, qualitative aspects of risk have been deprioritized as somehow less useful or relevant than quantitative factors. This shift toward quantification has been discussed in relation to human reliability ([29]) but also relates to ethical considerations as unquantifiable pieces of risk. No less critical is the capture of engineering as a discipline to the service of corporate interests over the public good, a process that has been long in development ([4]) and which has diffused into risk analysis as an engineering practice. For example, the announcement of risk task forces and “ethics watchdogs” in high-risk industries (e.g., AI) may contravene the goal of risk assessment (protection of the public) by presenting a façade of safety-consciousness that hides the continuation of risk.

3. HAZARD, PROBABILITY, AND RISK GOVERNANCE

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If the claim that engineering risk assessment is intrinsically political is to be more than suggestive, the key terms of the argument must be disaggregated. Discussions of risk often move too quickly between hazards in the world, the probabilistic representation of uncertainty, the evaluative constitution of risk, and the institutional practices through which assessments are used to authorize decisions. The concepts of hazard (as entity), risk and uncertainty (as probabilistic representations), and management (as practice) are analytically distinct, but practically entangled concepts. Hazards concern possible sources or causal propensities of harm. Probabilities are formal representations of uncertainty about the occurrence, magnitude, or timing of such harms. Risk, by contrast, is not merely the product of uncertainty and consequence, but the articulation of uncertain harm in a form oriented toward judgment and decision. Risk governance or management practices are the institutional invocations of such articulations in justifying action, inaction, prioritization, and toleration. These distinctions elucidate the political character of engineering risk assessment by emphasizing that it does not attach equally to each level. It is most visible where uncertain futures are rendered decision-relevant and made governable, though it also enters earlier through the framing choices that determine what will count as a hazard, a consequence, or a relevant uncertainty in the first place.

3.1. Hazard as the Causal Propensity of Harm

To maintain conceptual clarity, hazards must be distinguished from the later analytical and institutional forms through which they are represented. A hazard is here understood as a possible source of harm in the world, or more precisely, as a causal propensity by virtue of which harm may occur under certain conditions. In this sense, hazards belong to the world before they are modeled, categorized, or incorporated into a decision framework. This framing of hazards is common in risk assessments [23] and preserves a modest realism about engineered systems and their failures. This framing of hazards is common in risk assessments [24], and preserves a modest realism about engineered systems and their failures. Corrosive materials, unstable slopes, brittle components, and extreme hydrological conditions do not become hazardous only when they occur, or only when an analyst identifies them as such. They possess causal prerequisites that make certain kinds of damage possible, whether or not those possibilities are fully recognized in advance. Engineering practice itself depends on this assumption. Inspection, design, safety analysis, and failure mitigation would make little sense if hazards were treated only as artifacts of institutional or disciplinary labeling. To speak of hazard, then, is to refer to something more mind-independent than a subjective fear or administrative category. It is to refer to a feature, condition, or configuration of the world that can contribute to harmful outcomes.

Even if we recognize hazards as real causal propensities in the world, they are not naturally individuated, bounded, and ready for formal analysis. Where the underlying source of harm is real, its identification as *this* hazard rather than *that* one depends on acts of framing and abstraction. A chemical storage facility, for example, may be treated as a hazard because of explosion potential, groundwater contamination, chronic exposure risk, or cascading failures across adjacent infrastructure. Each of these characterizations may be justified, but they do not describe the same object at the same level of analysis. What appears as a single hazard in one context may be disaggregated into many in another, while what appear to be separate hazards may be treated as one when the decision context demands aggregation. The reality of hazards therefore does not remove the need for careful, reflective judgment. It only means that such judgment is exercised in relation to a world that is not exhausted by its representations.

This helps to clarify where the politics of risk assessment should and should not be located. The movement from hazard to risk requires choices that are not determined solely by the hazard. A hazard may be real, yet still admit of multiple descriptions, relevant consequence pathways, and modes of institutional significance (as in the chemical storage facility previously presented). Politics enters most clearly when these possibilities are selected, organized, and made decision-relevant – a process done by humans to serve human needs. The concept of hazard therefore anchors risk assessment in a world of real vulnerabilities and failure potentials, while leaving open the question of how those potentials are rendered meaningful for analysis and action. This distinction is important in engineering, where the practical aim is rarely to identify hazards in abstraction, but rather to determine which hazards matter,

under what conditions, for whom, and in relation to which system objectives. Once that step is taken, the analysis has already begun to move on from hazards to probability, consequence, and judgment. In other words, hazard names the worldly basis of possible harm, but it does not by itself determine the terms under which uncertain harm will be represented, compared, or tolerated. For that, a further conceptual step is required.

3.2. Probability as the Formal Representation of Uncertainty

Where hazards are sources of harm in the world, probability is the formal means by which uncertainty about those harms is rendered analytically tractable. This distinction is foundational to engineering risk analysis, devoted to assessing how likely a particular harmful event is, under what conditions it may occur, and with what range of possible consequences. Probability provides a disciplined language for addressing such questions – as Glenn Shafer put it, “probability is not really about numbers; it is about the structure of reasoning” [30]. Probability converts uncertainty into a form that can be modeled, reasoned about, and incorporated into decision processes. In this respect, probabilistic reasoning is one of the central achievements and critical requirements of modern risk analysis. This formal role should be stated clearly at the outset. Probability is not itself harm, nor is it risk: it is a representation of uncertainty regarding events, outcomes, or states of affairs. Such representations may be frequentist or Bayesian, and supported by data, models/simulations, or expert elicitation [15], [24], [29]. Regardless of the chosen perspective, probability in risk analysis renders uncertain futures legible for disciplined analysis and serves as an epistemic instrument to give uncertainty an analyzable form. The importance of this formalization is difficult to overstate. Without probabilistic representation, engineering would often be left with binary distinctions far too crude for most real decision contexts – systems rarely fail in all-or-nothing ways. Instead, system failure is often spectral: components age and degrade, protective barriers weaken, and interacting subsystems create uncertain failure pathways. Probability thus allows engineering analysis to register and distinguish among possible outcomes, and supports prioritization where resources, time, and attention are limited. It is for this reason that probabilistic methods have become so integrated into modern safety, reliability, and risk practice.

Yet the invocation of probability can also encourage misconceptions: as a precise and disciplined way of representing uncertainty, it can appear to provide a complete or objective account of what matters about uncertain harm. That conclusion, however, does not follow. Probability can represent uncertainty only with respect to something already selected for representation – relevant variables (events, scenarios, and outcomes) chosen to structure the problem within which probability is applied. A probability distribution does not tell us, by itself, which types of consequences *should* matter, how system boundaries *ought* to be drawn, or what level of abstraction or granularity is *appropriate* for analysis. These are prior acts of framing that render probability, while necessary, insufficient to specify risk in the sense at issue here. One may assign probabilities to various failures, but that does not determine which uncertainties are significant for decision, which combinations of outcomes matter, or why one possible harm should count more heavily than another. Probabilities remain formally silent on questions of salience, valuation, and tolerability. They can inform such judgments, sometimes quite powerfully, but they do not settle them. The probability of an event may be low while its social significance is immense. It may be high while its consequences are treated as routine. It may be uncertain in ways that are technically manageable yet politically unacceptable. Probability, in short, renders uncertainty measurable, but it does not render uncertain harm meaningful.

For present purposes, this point serves two functions. First, it preserves the legitimacy of probabilistic reasoning against any suggestion that the critique to come is anti-quantitative. The argument of this paper depends on the rigor of probabilistic methods and would make little sense without them. Second, it shows why a conceptual distinction must be maintained between probability and risk. Risk enters when uncertain harm is articulated in relation to valued outcomes, system purposes, decision thresholds, and possible interventions. That further articulation requires formal representation, to be sure, but it also requires judgment about what the uncertainty is *about*, why it matters, and how it should bear on action. Probability is therefore a necessary but not a sufficient condition for engineering risk assessment. Once this is recognized, the path to the next conceptual step becomes clearer. Hazards identify possible

sources of harm, and probabilities render uncertainty about them analytically tractable. Risk arises when those uncertain harms are organized for judgment within a decision context. It is at that point that questions of consequence, relevance, distribution, and tolerability move from the background to the center of analysis.

3.3. Risk as the Decision-Oriented Articulation of Uncertain Harm

While hazards identify possible sources of harm and probabilities render uncertainty about them analytically tractable, risk enters when uncertain harm is organized for judgment within a decision context. This is the point at which engineering analysis moves beyond the representation of possible events and toward the evaluation of what matters for action. Risk, in this sense, is not simply the coexistence of harm and uncertainty; it is the articulation of uncertain harm in a form that bears on choice, prioritization, intervention, and toleration. What makes risk distinctive is its orientation toward decision-making. It refers not only to what might happen, but to what should count, what should be compared, and what should bear on action under conditions of uncertainty.

This decision-oriented character helps explain why risk cannot be reduced to a function of hazard and probability alone. For engineering purposes, uncertain harm becomes risk only when it is related to valued outcomes, system purposes, operational constraints, and possible courses of action. A low-probability event may carry substantial weight because of irreversibility, public exposure, or cascading consequences. A more probable event may be treated as tolerable because its effects are localized, familiar, institutionally absorbed, or not fully understood. These are conclusions that arise when uncertain harms are placed within a field of practical judgment. For this reason, risk is always in part a framed object. To identify a “risk” is already to have selected a set of consequences as salient, a population as relevant, a timescale as meaningful, and a decision context as governing. That is, prior to even simple assessments such as expected loss or acceptable failure rate, one must first decide what counts as a loss, whose losses are included, and how harms are to be weighed, among other subjective decisions. Risk assessment often presents its outputs in compact and highly disciplined form, yet this concision is achieved only by organizing uncertain harm through judgments of relevance and comparability. Risk is therefore not, strictly speaking, a mind-independent feature of the world that is identified via PRA. It is cognitively constituted as an object of assessment.

This, however, does not make risk arbitrary or purely subjective. Risk remains constrained by the realities of hazard, the discipline of probabilistic reasoning, and the empirical adequacy of the models used. While necessary, risk is not exhausted by any of these. It is an evaluative synthesis in which uncertain harms are rendered meaningful in relation to purposes, values, and possible interventions. This synthesis is essential to engineering practice because decisions are rarely made in relation to uncertainty as such, but in relation to uncertain harms that have been judged relevant to safety, reliability, cost, or some other valued end.

The category of risk therefore names an intermediate but decisive level of analysis between mere uncertainty and institutional action. This distinction helps clarify why the politics of engineering risk assessment become more visible at the level of risk than at the level of hazard or probability taken alone. Once uncertain harm is made decision-relevant, questions of valuation and prioritization become unavoidable. Which consequences matter most? Which burdens may be imposed, and on whom? What level of protection is required, and what level of loss may be tolerated? These are not technical questions, even when they are addressed within highly technical frameworks. Rather, such questions are political – concerning how uncertain harm is translated into judgments that guide collective action. That is why risk, in engineering practice, should be understood as a decision-oriented articulation of uncertain harm rather than as a mere descriptor of possible loss. A further step, however, is still required. Risk becomes fully operative in engineering and public life when these articulated uncertainties are taken up by institutions to justify priorities, interventions, or toleration. That movement from assessed risk to authorized action is the domain of risk governance.

3.4. Risk Management as the Institutional Use of Risk

Risk governance (or management) is the institutional use of risk – as the decision-oriented articulation of uncertain harm – in justifying action, inaction, prioritization, and/or toleration. It names the domain in which risk assessments are taken up by organizations, regulators, operators, and publics as grounds for deciding what ought to be done, what may be deferred, and what forms of loss are acceptable. In this sense, risk governance is the broader practical context within which assessments acquire authority, force, and impact. Risk becomes governable when representations of uncertain harm are linked to decisions about intervention, resource allocation, design and operation limits, and public accountability. This institutional dimension is particularly relevant because, outside of academic exercises, risk assessment is rarely performed for contemplative purposes. Its outputs are ordinarily embedded within structured settings of action: Risk and reliability analyses may inform licensing and inspection decisions, guide capital planning efforts, and/or shape incident response practices. The point of analysis is not only to describe uncertainty, but to furnish reasons for adopting particular actions or policies. Risk governance is the translation of analytical output into practical authorization.

In risk governance, the evaluative dimensions of risk become especially difficult to ignore. Institutions do not govern hazards in the abstract, nor do they govern probability distributions as such. Rather, they govern by deciding which uncertain harms warrant mitigation, which may be accepted, and which populations will be exposed to them. These decisions are, fundamentally, not exhausted by technical adequacy. Risk governance extends technical methods to involve judgments about legitimacy, responsibility, burden-sharing, public standing, and the tolerability of loss and for whom. A system may be judged “safe enough” by one criterion, but unacceptable to those who bear the greatest exposure. Alternatively, a system may embody risks that are politically or ethically difficult to justify, but inefficient to mitigate. Risk governance is therefore the point at which risk assessment becomes overtly connected to politics – the ordering of collective life. For this reason, risk governance cannot be treated as though it simply begins after technical analysis has been completed; the relationship runs in both directions. Institutional purposes and incentives, regulatory and liability frameworks, and public expectations often shape the structure of the assessment itself. What is modeled, which scenarios are included, how consequences are grouped, what thresholds matter, and what kinds of uncertainty are treated as actionable are often conditioned by what can be managed. Risk governance is thus part of the environment within which PRA findings are produced, stabilized, and rendered usable.

This point helps clarify where the political dimension of the present argument is strongest. Politics does not attach equally to every stage of analysis, but becomes most visible where articulated uncertainties are taken up as reasons for sanctioning exposure, distributing protection, and legitimating intervention or nonintervention. At the level of governance, questions of acceptable loss, unequal vulnerability, and public justification move to the foreground. Thus, the political force of management reveals the political character of risk analysis itself: Designed to support such decisions, the judgments embedded within risk analysis cannot be treated as purely technical preliminaries because they are part of the same practical enterprise by which uncertain futures are rendered governable. The distinction between risk and risk governance is therefore analytically useful but ultimately incomplete. While risk is the form uncertain harm takes when organized for decision, risk governance is the institutional uptake of that form in organizing action. Once this relation is made explicit, it becomes easier to see why the movement from hazard to probability to risk cannot be understood as separate stages in a linear sequence of descriptions. At each stage, uncertain harm is being shaped for use within a field of judgment. With this in view, it is necessary to examine more closely the framing choices that mediate this movement and make technical risk assessment possible in the first place.

4. Beyond the Triplet: Toward a Politically Adequate Risk Assessment

If the preceding argument is correct, then the problem with orthodox engineering risk assessment is not that it is quantitative, formal, or scientific, but rather that these strengths are too often treated as sufficient. The risk triplet provides an indispensable framework for disciplined reasoning about uncertain harms, but it does not by itself capture the full set of judgments through which uncertain harm becomes decision-relevant. Understanding risk as political does not minimize the importance of risk

analysis in evaluating and ensuring system safety, nor does it imply that risk analysis is in some sense unscientific. It instead clarifies the reality of a discipline coupled simultaneously to technical engineering requirements and social mandates. A politically adequate risk assessment must therefore retain the analytic virtues of probabilistic reasoning while making explicit the evaluative commitments on which its outputs already depend. The task, then, is to recognize that risk assessment already contains normative and political judgments, and that better practice requires those judgments to be explicit, structured, and ultimately made available for critical scrutiny.

Recognizing the social and political inputs and outputs of risk analysis also has constructive implications for practice. It permits analysts to consider more deeply the impact of technology and risk on society, and to identify governance instruments responsive to both technical and social dimensions of uncertain harm. On this view, factors such as the distribution of consequences, the allocation of total risk burden, and the standing of affected populations are not external moral concerns appended after the analysis is complete. They are part of what makes the analysis adequate to the object it purports to assess. To say this is simply to insist that the risk triplet does not exhaust what must be known when uncertain harms are being rendered actionable within collective life.

Such an approach begins by treating the risk triplet as necessary but incomplete. The questions of what can go wrong, how likely it is, and what the consequences will be remain central. Yet they must be supplemented by a further set of questions that the triplet does not answer on its own. Which consequence classes are being counted, and which are omitted? Whose harms are included in the analysis, and whose are backgrounded? How are near-term and long-term effects being weighted? Which distributions of burden are treated as acceptable? What uncertainties are considered decision-relevant, even where consequence pathways remain difficult to enumerate or quantify? These kinds of questions are part of the work required to determine what the analysis is about and what practical authority it should carry. What is needed, then, is a more explicit formalization, for risk analysts, of the social and political components of risk alongside the technical components of the triplet. Risk assessment must look beyond the triplet for a more robust account of uncertain harm, one capable of connecting probabilistic representation with the evaluative and governance concerns that already condition its use.

A broadened assessment framework should therefore include at least four additional dimensions. The first is distribution. Aggregate expected loss is often insufficient for decision-making because it obscures the question of who bears the harm and who receives the benefit. A risk that is acceptable in aggregate may remain unjustifiable if its burdens fall predictably on those with the least power, the least voice, or the fewest alternatives. The second is temporal profile. Many engineering decisions distribute harms across time in ways that are not captured well by event-based consequence accounting. Chronic, cumulative, path-dependent, and delayed harms require a richer evaluative vocabulary than the triplet alone provides. The third dimension is agency and standing. People do not evaluate risk only in terms of outcome magnitude. They also care whether they consented to the exposure, whether they have control over it, and whether they have meaningful standing in the decisions that govern it. The fourth dimension concerns uncertainty about consequence classes themselves. In some domains, especially those involving sociotechnical transformation, the central difficulty is not that probabilities are hard to estimate, though that is a serious challenge. It is that the relevant forms of harm are epistemically opaque, i.e., not yet feasibly enumerable. In such cases, the insistence on quantification can conceal rather than clarify what is at stake.

This broader framework also has implications for participation. The argument of this paper does not require that all risk assessments be replaced by plebiscitary procedures, nor that expert judgment lose its privileged role in technically demanding domains. It does, however, require abandoning the view

that stakeholder perspectives are relevant only after the real assessment has been completed. If risk is partly constituted through judgments of salience, burden, tolerability, and legitimacy, then affected publics are potential sources of insight into what the analysis ought to count as consequential in the first place. Participation, on this view, is one important means of improving the adequacy of the assessment by broadening its sensitivity to forms of harm that formal models alone may neglect.

None of this entails that every concern should be translated directly into a metric, or that all values must be commensurated within a single decision calculus. Indeed, one of the lessons of the preceding analysis is that some politically salient features of risk resist straightforward quantification, and that is okay. The point is that what cannot be cleanly measured must not, on those grounds, be treated as irrelevant. A politically adequate risk assessment will often need to combine formal probabilistic methods with structured qualitative judgment, explicit ethical reasoning, and institutional mechanisms for public justification. Its aim is disciplined practical judgment under conditions of uncertainty, plurality, and unequal vulnerability.

The value of such an approach becomes especially clear in contexts where the consequences of technical systems exceed the boundaries of familiar safety engineering. Artificial intelligence is an obvious example, though not the only one. In such cases, the most important harms may be diffuse, cumulative, difficult to enumerate in advance, and bound up with questions of power, institutional dependence, and public life itself. Here the language of risk remains useful, but only if expanded beyond a narrow focus on probabilistically tractable failure events. The resulting challenge is to ask what forms of life, what distributions of agency, and what kinds of public order are being rendered vulnerable by the systems under assessment.

5. DISCUSSION

The argument developed here is likely to invite two misunderstandings. The first is that to call engineering risk assessment political is to deny its scientific status. The second is that to broaden risk assessment beyond the triplet is to collapse disciplined analysis into unstructured moralism or public anxiety. Neither conclusion follows. As Hansson and Aven observed, risk analysis can remain scientific even while incorporating norms and values [27]. The presence of normative judgment does not disqualify a practice from scientific standing. It shows, rather, that scientific inquiry in applied settings often depends on background judgments about relevance, acceptable error, and the practical consequences of being wrong. In the case of risk assessment, these judgments are especially visible because the practice is oriented toward action under uncertainty rather than toward description alone. Its object is not simply the world as it is, but the world as it may become under conditions that demand anticipation, intervention, and justification. The scientific status of risk analysis is therefore compatible with its political character. Indeed, the latter helps explain the practical authority of the former.

The more difficult question is how far the political thesis should be taken. This paper has not argued that hazards are political inventions, nor that probabilistic methods are merely ideological instruments, nor that formal risk analysis is incapable of disciplined insight. The claim has been narrower and, for that reason, stronger. Hazards may be real features or propensities in the world. Probabilities may represent uncertainty with considerable rigor. But risk, as an object of engineering assessment, is constituted only when uncertain harm is organized in relation to valued outcomes, decision thresholds, and possible interventions. That constitution depends on judgments about harm, relevance, distribution,

and tolerability. Since those judgments concern the legitimate ordering of collective life under conditions of plural values and unequal vulnerability, they are political in the sense defined at the outset. This understanding also clarifies why the tension between expert assessment and public concern should not be treated as a simple conflict between rationality and irrationality. Public perceptions of risk often register dimensions of exposure that formal analysis has difficulty representing: dread, consent, dependence, asymmetry of benefit and burden, and distrust in the institutions authorized to manage exposure. These concerns are sometimes poorly articulated, and they can certainly be distorted. Yet they are not, for that reason, epistemically empty or otherwise irrelevant to risk engineering. In many cases they reveal that what is being contested is the framing of the risk object itself. The dispute is over which harms count, whose perspective is taken as authoritative, and what kinds of loss may be normalized in the name of optimization, innovation, or efficiency.

The implications for engineering are significant. If risk assessment is intrinsically political in this sense, then the responsibilities of engineers and risk analysts cannot be exhausted by technical competence alone. Their task includes reflective attention to the categories through which harm is rendered visible, the populations whose exposure is normalized, and the institutional settings in which analytical outputs become reasons for action or inaction. This requires only that engineers understand risk assessment as a mode of public reasoning rather than as a purely internal technical exercise. The social duty of engineering is not an external moral supplement to otherwise self-contained analytic work. It is partly internal to the conditions under which that work becomes publicly meaningful and justifiable.

A final implication concerns the kinds of systems for which present risk practices are best suited. Conventional probabilistic methods remain highly effective where hazards are relatively well characterized, consequence classes are enumerable, and institutional aims are stable. They become more strained where harms are systemic, cumulative, socially mediated, or bound up with transformations of collective life. In such domains, the aspiration to remain within the boundaries of formal calculability can itself become a source of blindness. The challenge, then, is not to abandon rigor, but to develop forms of rigor appropriate to risks whose most significant dimensions are evaluative, distributive, and political as well as technical.

6. CONCLUSION

This paper has argued that engineering risk assessment is intrinsically political because the specification, quantification, and evaluation of risk depend on normative judgments about harm, relevance, distribution, and tolerability. The claim is not that hazards are unreal, nor that probabilistic methods lack scientific value, nor that public concern should displace technical expertise. It is that the transformation of uncertain harm into assessed risk already presupposes judgments that no technical procedure can supply on its own. Risk assessment does not simply discover an object ready-made in the world. It constitutes uncertain harm as an object of decision and, in doing so, helps organize the terms on which exposure, protection, and acceptable loss are publicly justified.

Once this is recognized, the limitations of the orthodox risk triplet appear in a different light. Rather than methodological gaps that can be patched with better data or finer models, instead they mark the point at which formally tractable uncertainty meets questions of collective life that exceed formal tractability alone. A politically adequate risk assessment must therefore preserve the rigor of probabilistic analysis while broadening its evaluative frame. It must ask not only what can go wrong, how likely it is, and what its consequences may be, but also for whom those consequences matter, how they are distributed, what forms of loss may be tolerated, and under what conditions such toleration could be publicly justified.

To understand risk assessment in this way is, quite literally, to take engineering more seriously. Engineering decisions shape worlds, distribute vulnerabilities, and authorize specific futures. Risk analysis is one of the principal means by which those futures are rendered governable. Its responsibility is therefore not exhausted by technical adequacy. It also includes the reflective and public work of determining which uncertain harms should count, which should not be normalized, and what it means to act responsibly when the object under assessment is not merely a system, but a shared form of life.

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