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Methods for elicitation of risk preferences and perceptions

An examination of individual and group risk preferences

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Abstract

Risk fundamentally influences strategic planning, investment management, and policy formulation across businesses, governments, and communities. Accurately measuring risk preferences and perceptions at both individual and community levels is indispensable for informed decision-making, particularly in community resilience planning. This NIST Special Publication explores the definition of risk, its application, and its importance in the community resilience domain, and disentangles relative aspects of risk, including risk behavior, risk preference, risk perception, and risk attitude. We delve into how risk preferences and risk perceptions influence decision-making and outline various methods for eliciting associated risk behavior. These methods include but are not limited to incentivized games and data collection instruments, highlighting the different techniques used to gauge how individuals perceive risks.

We report on various methods to measure and aggregate risk preferences within groups. Current methods are insufficient in deriving accurate group risk preferences from individual data and fail to fully address the complexities of group interactions. Addressing this gap requires the development of more refined and robust methods to ensure accurate representation of group risk preferences, thereby enhancing community resilience strategies. This NIST Special Publication underscores the critical role of risk preference elicitation, highlights challenges in aggregating individual preferences to the group level, and advocates for improved aggregation methods to support resilient community planning.

Keywords

Community resilience planning; Risk measurement; Risk perception; Risk preference.

Table of Contents

List of Tables

1. Introduction

The inherent uncertainty of life constitutes a fundamental and multifaceted aspect of the human experience. Uncertainty significantly influences decision-making at all levels, permeating both the quotidian – the preparation of meals – and the momentous – the selection of a career path or life partner. As such, uncertainty is at the very core of decision-making. Stemming from diverse factors such as technological advancements, and socioeconomic shifts, uncertainty underscores the importance of understanding and addressing risk preferences and perceptions at both individual and community levels. Given the pervasive nature of uncertainty in our lives, it becomes imperative to address its implications, particularly in critical areas such as community resilience planning.

Predicting the precise nature and severity of future shocks and persistent stressors is challenging, especially with the added complexity introduced by climate change, which brings about unpredictable weather patterns and changes in baseline conditions [126]. The long-term impacts of climate and weather-related shocks are often difficult to foresee. For instance, while a hurricane may cause immediate destruction, its economic and social consequences can persist for years. Additionally, disasters frequently lead to secondary crises, such as power outages or infrastructure failures, further complicating the situation. Public perception of risk plays a crucial role in these decisions. If a community or its decision-makers do not perceive a significant threat, they may be less inclined to support costly resilience projects, particularly when there is uncertainty about the likelihood of a disaster and the extent of its potential impact. This underscores the importance of accurately assessing and communicating risk to ensure informed and effective community resilience planning.

Much research across disciplines has focused upon the importance of risk preferences and perceptions to inform kingmaking and these are incorporated into well-known theories, such as utility theory ([14], [61], [104]). The importance of accounting for these factors has been consistently emphasized in the literature ([36], [90], [142]). Researchers have developed and refined various methods to understand how individuals make decisions under uncertainty ([36], [61]). This report includes a few examples of methods to measure risk preference and risk perception arising from an unstructured literature review of risk across the domains of economics and psychology.

We conducted a review of the literature to explore the existing methods used to elicit individual risk preferences and perceptions. Given the vast landscape of research, our findings represent only a portion of the available methods, and largely arise from segments of the economics and psychological literatures. The identified methods range from simple survey techniques to more complex experimental designs, such as incentivized games and investment tasks. Additionally, we explored how individual-level preferences can be aggregated to reflect group or community-level risk preferences. We refer to 'aggregation' as the process of compiling and synthesizing individual risk preferences into a community-level preference using a range of techniques beyond simple mathematical summations. We have identified several methods that provide insights into the approaches researchers have used to extract group-level risk preferences. However, the

aggregation of these individual preferences to infer group or community-level risk preferences still requires more research and refinement.

Based on our review of the literature, we identified a notable gap in the methods available for assessing community risk preferences. While there are well-established methods for measuring individual risk preferences and perceptions, there is room for additional research on community-level risk preferences and perceptions to appropriately inform community-level decision-making. This gap poses a significant challenge to the development of effective measures in community resilience planning and other areas where decisions are made by a group. We aim to highlight this critical research gap and underscore the importance of developing and refining methods that can capture the complexities of community risk preferences and perceptions. Addressing this need is essential for informed policy-making and strategic planning that can enhance community resilience in the face of uncertainties and potential disasters.

This report is divided into four sections. First, we define risk and associated aspects, such as risk preferences and perceptions. In the second section, we provide an overview of a few of the available methods for eliciting individual risk preferences and perceptions. We then delve into an exploration of group risk preferences in Section 3, examining methods for aggregating individual preferences to derive group-level insights. Finally, we consolidate our findings, outlining key insights gleaned from our investigation and proposing avenues for future research.

2. Defining risk

Defining risk in the context of community resilience planning is complex, as the concept of risk varies across different academic disciplines. In this report, we explore definitions of risk across various fields that are related to community resilience planning. *Risk*, in Webster's dictionary, is defined as both a noun and a verb. As a noun, it is defined as "a possibility of loss or injury" or "the chance or probability of loss," "the perils to the subject matter of an insurance contract," and "the chance that an investment (such as a stock or commodity) will lose value." As a verb, it is defined as "to expose to hazard or danger" or "to incur the risk or danger of something." Similar to Webster's definitions for a noun, the American Psychological Association (APA) [2] defines risk as "the probability or likelihood that a negative event will occur" or "the probability of experiencing a loss to harm that is associated with an action or behavior." Health and environmental sciences share similar definitions of psychology although the negative event is a harmful event relating to human health or ecological systems. US Environmental Protection Agency (EPA) [136] defines risk to be, "the chance of harmful effects to human health or to ecological systems resulting from exposure to an environmental stressor." In line with the definition put forward by the APA, finance traditionally defines risk as the "uncertainty associated with the financial loss" [100].

Although many disciplines define risk as the probability of a negative event, in economics, it can be associated with both negative events (e.g., a potential loss) and positive events (e.g., gains from a lottery). Economists tend to associate risk more with uncertainty rather than if that uncertainty is connected to a positive or negative event [26]. The International Standard Organization ISO31000 defines risk as "the effect of uncertainty on (the achievement of) objectives" ([62], [96]). Sharing this ideology, in the field of finance, investments, and insurance, risk is also defined by Damodaran [27] as "the likelihood that we will receive a return on an investment that is different from the return we expect to make." This definition emphasizes that risk encompasses both negative and positive outcomes.

Social sciences and policy analysts view risk from the social and subjective side of risk to identify the policy implications. Beck [10] defines risk as a "systematic way of dealing with hazards and insecurities induced and introduced by modernization itself." Rosa incorporates the social dimension with uncertainty by stating "risk is a situation or an event where something of human value (including humans themselves) is at stake and where the outcome is uncertain" [111]. The context of engineering and risk management is slightly different from the above; Risk refers to "the composite measure of an event's probability of occurring and the magnitude or degree of the consequences of the corresponding event" [97]. Šotić [128] defines it as the "product of probability of the occurrence of an adverse event and the weight of the consequences of that event." Similarly, in the view of disaster mitigation sciences, the concept of risk is defined as, "the potential (not actual and realized) disaster losses, in lives, health status, livelihoods, assets and services, which could occur in a particular community or society over some specified future time period" or "the product of the possible damage caused by a hazard due to the vulnerability within a community" by the United States Agency International Development [136].

It is evident from the above discussion that the diverse definitions of risk stem not only from the varied contexts and nature of the problems under consideration, but also from the different disciplinary backgrounds of researchers (e.g., coming from economics, engineering, and psychology). The psychological definition emphasizes the probability of negative outcomes, while the economic or financial definition considers both potential gains and losses. We can see that social sciences view risk as a societal construct involving human values and uncertainties, and engineering defines it based on the probability and magnitude of consequences. In the context of this paper, we use the following definition of risk: the likelihood of occurrence of an uncertain event, as it addresses the human construct and uncertainties relevant to community resilience. When confronted with this uncertainty, individuals respond through actions shaped by their risk behavior, which reflects how they navigate and manage potential outcomes. Risk behavior refers to the actions individuals take when faced with uncertainty, influenced by their risk preferences and perceptions.

2.1. Risk preference

An individual generally considers all available options and seeks to maximize their satisfaction or utility, reflecting a core principle of the theory of choice [76], which is closely related to the study of risk preferences. Considering an individual's personal preferences, each available option is weighed against the potential benefits and costs to select the one that best aligns with their goals and values. Risk preference is a person's preference over certainty when given a choice between different options with uncertain outcomes. In other words, it refers to the risk a person is willing to take based on the expected utility or satisfaction of the outcome. These preferences, which encompass individual's attitudes towards uncertainty and their willingness to take risks, play a crucial role in shaping behavior and influencing choices.

Though economics and psychology both employ the term "risk preference," the definitions differ across the two disciplines [90]. Psychology focuses on the behavioral aspect, as Hertwig [58] refers to it as "the propensity to engage in behaviors or activities that, although rewarding, involve the potential for loss or harm (for oneself or others)." While the economics and finance disciplines focus on the outcome of the action, Rigdon [110] views it as "the tendency to choose an action that involves higher variance in potential monetary outcomes, relative to another option with a lower variance of outcomes (with equal expected value)." The economic reference underlines the uncertainty involved around the event independent of whether the outcomes involve gains or losses.

Often researchers across fields classify individuals into categories based on their individual propensities towards risk-taking by analyzing the decisions they make over different uncertain outcomes. Economics defines a risk-neutral individual as someone who will always select the option that has the highest expected value, even if there is high uncertainty surrounding the outcomes of the option with a higher value [58]. For example, if you give someone the option between a bet with a 50 percent chance of winning $100 and a 50 percent chance of winning $0, then a risk-neutral individual would be willing to pay $50 to buy a ticket for that lottery since $50 is the expected value of the lottery. A risk-averse individual would only be willing to pay less than

$50 for the same lottery described above. There is a wide range of levels of risk aversion, so someone with extremely risk-averse preferences may only be willing to pay $25, while someone who is only slightly risk-averse may be willing to pay $45 for the same lottery. In an economic framework, an individual would be considered risk-seeking, if they would be willing to pay more than the expected value for an uncertain outcome, so they would be willing to pay more than $50 for the same lottery presented above. In economics, the level of risk aversion of an individual is defined by "the concavity of the utility function" or "the negative of the second derivative of the utility function" ([141], [144]). Risk aversion has also been defined by Qualls and Puto [105] as a decision maker's "preference for a guaranteed outcome over a probabilistic one having an equal expected value."

The psychology field tends to focus on behavior and use narrative terms for communicating risk preferences. In her two-factor theory, Lopes [81] described risk-averse and risk-seeking people in the discussion between security versus potential. She notes that "risk-averse people appear to be motivated by a desire for security, whereas risk-seeking people appear to be motivated by a desire for potential." March and Shapira [86] describe "individuals or organizations that pursue actions with small variability in outcomes as either 'reliable' or 'risk averse' depending on the context. Those that pursue actions with large variability in outcomes can similarly be described either as 'unreliable' or 'risk-seeking.'" More recently, Hertwig [58], broadened the interpretation of risk preference to underline the complexity of risk preference by incorporating constructs such as impulsivity, sensation-seeking, novelty-seeking, and impulse control. These perspectives collectively emphasize the diverse motivations and interpretations behind risk preferences, illustrating the need for nuanced approaches to studying and understanding risk-related behaviors and how the narrative of risk preferences has evolved over time.

2.2. Risk perception

Risk perception is a person's subjective judgment concerning a given risk [126]. Sjoberg et al. [123] defined it as the subjective valuation of the likelihood of a specified type of accident or incident happening and how concerned we are with the consequences. Schroeder et al. [116] note that "Risk perceptions represent a person's views about risk inherent in, or riskiness of, a particular situation." APA [2] also defines it as "an individual's subjective assessment of the level of risk associated with a particular hazard (e.g., health threat)." It is factored by various individual characteristics, experiences, and information ([2], [6], [13], [51] , [94], [107], [109], [115], [123], [147]). Kirby [69], borrowing from a sociological point of view, agrees that "the individual's perception of risk is usually dependent upon a social representation, which can be defined as a culturally conditioned way of viewing the world and the events that take place there." Hence, perceptions may change when new information or experience has been encountered, while preference is a more consistent individual trait. Theories about risk perceptions have identified two main types based on the origin of the risk [40]. Deliberative risk perceptions are systematic, logical, and rule-based, involving careful analysis and reasoning about the risk. On the other hand, affective or experiential risk perceptions are based on emotions and experiences, referring to the feelings associated with the risk, or the intuitive impressions people have about it. These two

types highlight the dual nature of how individuals perceive and respond to risks, combining both rational and emotional elements.

2.3. Risk attitude

Risk attitude is a characteristic that, while interconnected with risk preference and risk perception, encompasses a broader and more general conceptualization of risk. Schroeder et al. [116] indicate that "Risk attitudes describe a person's overriding tendency toward risk in a consistent way across different risky situations." It refers to an individual's inclination towards risk-taking or risk-averse actions. Risk attitude can be categorized into risk averse, risk neutral, and risk-seeking, which identify an individual's comfort level with risk and approaches to decision-making. Schroeder [116] explains, "Risk-averse people place a high premium on assured safe(ty), relative to risky ventures. Risk-neutral people are indifferent among choices with different levels of risk, and risk-seeking individuals (e.g., gamblers) pursue risky situations." Risk attitude and risk preferences, though measured on similar scales, are distinct as risk attitude reflects a general disposition towards risk, risk preferences pertain to specific choices among risky options and vary depending on the context. Risk behavior, which we use as a term to refer to the choices and realized actions, is dependent on both risk perceptions and risk preferences ([101], [144]). It is a manifestation of how people respond to real world situations when confronted with uncertain outcomes.

While risk attitude, perception, preference, and behavior are related concepts, they are distinguishable as they apply to different aspects of decision-making. Take, for instance, an individual who is making the decision to purchase insurance for their house to protect against flooding. Risk perception is how the individual perceives the risk of flooding, such as the likelihood or potential damage. An individual's general tendency towards taking action against potential damage, such as a risk-taking approach or a risk-averse approach, is termed risk attitude. The individual's preference over uncertain outcomes (e.g., uncertain cost of flood damage) describes the individual's risk preference. Risk behavior is influenced by risk attitude, perception and preference, and possibly other factors that play a role in decision-making, such as financial condition and demographic characteristics. Understanding risk preferences, perceptions, attitudes, and behavior is important in community resilience planning ([6], [22], [44], [45], [59], [82], [91], [107], [113], [114], [135], [142], [150]) so decision-makers can better anticipate how individuals and groups will respond to various risks, leading to more informed and effective strategies. By employing diverse measurement techniques, researchers can better understand how risk influences behavior and inform the development of effective strategies to manage and mitigate potential hazards, which we will discuss in the following section.

3. Eliciting risk behavior

Given the critical role of risk behavior in decision-making, researchers across disciplines – here, we focus on psychology and economics – have devised numerous methods to gauge an individual's risk preferences and perceptions. These approaches aim to capture how individuals perceive and respond to uncertain situations, providing valuable insights into their decision-making processes. We provide a brief, though not comprehensive, overview of some of the available techniques to measure risk preferences and perceptions.

3.1. Risk preference elicitation

The measurement of risk preferences involves a multidimensional approach that draws insights from various disciplines, such as psychology, economics, and behavioral science. As such, accurately measuring risk preferences is essential for researchers, policymakers, and practitioners who need to assess an individual's behavior to design effective measures. A wide range of elicitation methods have been developed to measure risk preferences across domains. Risk preferences are typically measured using real time incentivized games and experiments ([4], [19], [59], [61], [82]) or using data collection instruments ([5], [30], [63], [84]).

3.1.1. Incentivized games

Incentivized games typically engage participants with some type of monetary incentives, as these involve participants making decisions in various scenarios that involve risk and the decision that impacts their earnings. By linking choices to outcomes that directly impact a participant's earnings or payoffs, incentivized games create a high-stakes environment that mirrors real-life decision-making situations ([9], [61]). These games can be formatted in lottery-style choices, investment games, or risk-taking tasks. The lottery-style tasks tend to offer the participants a list of hypothetical lottery options associated with different probabilities and payoffs, encouraging them to choose their most preferred option. The investment game asks the participants to make investment choices by allocating finances across various portfolios and assets, which provides insights into the risk nature and investment strategies. Incentivized games allow the researchers to capture real preferences of individuals, in action with immediate consequences in a controlled environment. Due to this aspect, economists have an inclination towards the incentivized experimental style of understanding risk perceptions [36], however, these methods demand a considerable time commitment from participants, whether conducted online or in person.

The multiple price list method is a technique to elicit risk preferences [85] that involves providing the participant with a series of choices between two options, a safe option, and a risky option, with varying probabilities and payoffs. Participants indicate their preference for each choice, allowing researchers to observe the point at which they switch from preferring the safe option to the risky one. Holt and Laury [61] take an approach that is a specific application of the multiple price list method designed to measure risk aversion. This method uses varying risk and return for the respondents to make multiple choices between the given pairs of lotteries, usually with a smaller but more certain payoff and another with a larger but less certain payoff. As in the expected utility theory, the switch point at which the participants transition from preferring a

safe option to a risky one allows the researcher to infer the risk preferences ([9], [15]). Table 1 shows an example of the Holt and Laury method, where the increasing and decreasing probabilities for the associated payoffs can be observed. The monetary amounts in option B are more variable than in option A, making option B the riskier option. The probability of the high payoff for both options is 1/10 (first option); Option B is likely to be chosen only by an extreme risk seeker. As the probability of the high payoff option increases as we move down the table, the participant would cross over to Option B. Generally, if participants consistently opt for the safer, lower-risk option across multiple pairs of lotteries, it indicates a higher level of risk aversion. Conversely, if participants consistently choose the riskier option with higher potential payoffs despite greater uncertainty, it suggests a higher tolerance for risk.

Table 1. Example of the lottery-style questions (Holt and Laury, 2002).

Option A	Option B	Expected Payoff difference
1/10 of $2.00, 9/10 of $1.60	1/10 of $3.85, 9/10 of $0.10	$1.17
2/10 of $2.00, 8/10 of $1.60	2/10 of $3.85, 8/10 of $0.10	$0.83
3/10 of $2.00, 7/10 of $1.60	3/10 of $3.85, 7/10 of $0.10	$0.50
4/10 of $2.00, 6/10 of $1.60	4/10 of $3.85, 6/10 of $0.10	$0.16
5/10 of $2.00, 5/10 of $1.60	5/10 of $3.85, 5/10 of $0.10	-$0.18
6/10 of $2.00, 4/10 of $1.60	6/10 of $3.85, 4/10 of $0.10	-$0.51
7/10 of $2.00,3/10 of $1.60	7/10 of $3.85,3/10 of $0.10	-$0.85
8/10 of $2.00, 2/10 of $1.60	8/10 of $3.85, 2/10 of $0.10	-$1.18
9/10 of $2.00, 1/10 of $1.60	9/10 of $3.85, 1/10 of $0.10	-$1.52
10/10 of $2.00,0/10 of $1.60	10/10 of $3.85,0/10 of $0.10	-$1.85

Eckel and Grossman [37] use a similar lottery style risk perception elicitation method. Table 2 shows an example of the Eckel and Grossman method. It presents participants with 50-50 gambles, where the gains in expected value can only be obtained with an increase in risk. Table 3 illustrates the various payoffs, highlighting the increasing levels of risk associated with each option.

Table 2. Example of the lottery-style questions (Eckel and Grossman, 2002).

Lottery 1	50%	A	€4	◉
	50%	B	€4	
Lottery 2	50%	A	€6	◉
	50%	B	€3	
Lottery 3	50%	A	€8	◉
	50%	B	€2	
Lottery 4	50%	A	€10	◉
	50%	B	€1	
Lottery 5	50%	A	€12	◉
	50%	B	€0	

Source: Filippin's[42] elaboration of Eckel, C.C., and P. J. Grossman. "Sex differences and statistical stereotyping in attitudes towards financial risk." Evolution and Human Behavior 23:4 (2002): 281-295 (4).

Unlike the Holt-Laury method, which involves a series of choices with varying probabilities, the Eckel-Grossman method requires participants to make a single choice among the set of lotteries. The chosen lottery is played, and the participant is paid accordingly at the end of the experiment in an incentivized version of this question. The possible reward increases along with the associated risk. The simplicity of this method can make the task easier for participants and reduce potential confusion [92]. Though simple, this method effectively evaluates risk preferences and maintains the necessary heterogeneity for estimating utility parameters.

Table 3. Example of Eckel and Grossman style lottery choice question.

Lotteries (50/50 chance)	Low payoff	High Payoff	Expected value	Variance
Lottery 1	€4.00	€4.00	€4.00	€0.00
Lottery 2	€3.50	€5.00	€4.25	€1.60
Lottery 3	€3.00	€6.00	€4.50	€2.12
Lottery 4	€2.50	€7.00	€4.75	€3.18
Lottery 5	€2.00	€8.00	€5.00	€4.24
Lottery 6	€1.00	€9.00	€5.00	€5.66

Gneezy and Potter's method [52] demonstrates another method for assessing an individual's risk preferences through an investment scenario. In this method, participants receive a sum of money, $X and are asked to decide how much of the amount they want to invest into a risky option while keeping the rest. The risky option entails a probability, p, of yielding a dividend of $k * x. The money that is not invested will be kept by the participant. The parameters p and k are chosen such that investing more always raises the expected value and the variance. The value $x, which is the only decision participants make in this experiment, is thus the measure of risk aversion. The method is created such that risk neutral participants should invest the entire amount while the risk averse participants are likely to invest part of their money based on their level of risk aversion. Essentially, the participant's decision on how much money to invest then allows the researcher to calculate their risk preference ([33], [60]).

There are other computerized methods, which aim to assess risk preferences. Such methods aim to simulate real-world risk-taking situations, allowing researchers to observe participant's risk preferences and decision-making strategies. Balloon Analogue Risk Task (BART) [75] is a popular method where participants inflate a virtual balloon, gaining money with each pump but risking the balloon popping and losing all accrued rewards [53]. The BART is particularly useful in capturing individual differences in risk tolerance. Participants who pump more air into their balloon are considered to have higher risk tolerance, as they are willing to risk losing all accrued rewards for the chance of a higher payoff. The Columbia Card task (CCT) [41] is another method, where the participants select cards from 32 face-down cards. A gain card equals a specified positive amount and the chance to continue the trial whereas a loss card equals a specified subtraction from the previous payoff and ends the task. The number of cards selected before stopping indicates the participant's risk preference, with more selections suggesting higher risk tolerance. The task can differentiate between decisions made under emotional conditions and those made under cognitive conditions, providing insights into how emotions influence risk-

taking. It helps identify individual differences in risk behavior, including how people weigh potential gains against the probability of losses. These approaches help reveal nuances in risk behavior by illustrating how an individual's risk preferences can vary widely, depending on the context and format of the elicitation method. The multiple price list methods allow for detailed distinctions between risk neutrality and risk seeking behaviors with the precise adjustments of probabilities and payoffs. Furthermore, the computerized methods help simulate real-world risk-taking scenarios, providing deeper insights into the cognitive processes and personality traits that influence risk behavior.

3.1.2. Data collection instrument

Data collection instruments such as surveys, questionnaires, interviews, or focus groups support the process of systematically gathering self-reported information about an individual's preferences regarding risk. The surveys attempt to ask people about their preferences or willingness to take risks, for hypothetical scenarios or general risk questions. There are several approaches used by researchers, such as a multi-item questionnaire advocated by Dohmen et al. (2011) style questions, Likert scale questions, and lottery choice questions.

One example of a survey question to gather risk preferences is the "general risk question." An example of a general risk question is "Are you generally a person who is willing to take risks, or do you try to avoid taking risks?" The response to this question can be rated on a scale, such as a 5 or an 11-point Likert scale, allowing participants to indicate their level of agreement or disagreement ranging from "not at all willing to take risks" to "very willing to take risks [31]." This method has been used widely across domains in predicting risk behavior ([5], [30], [73]).

The Dohmen et al., [30] style question is another method used to elicit risk preferences in a simple and intuitive format on an 11-point scale. The participants are presented with hypothetical scenarios and are asked to indicate their preference corresponding to each scenario on a scale of 0 to 10, with 0 representing complete aversion to risk and 10 representing complete willingness to take risks ([63], [84]). The scenarios are curated such that the responses reveal underlying psychological characteristics and preferences. For example, the participants are presented with risk propensity questions or a set of lotteries and are asked to indicate their willingness to take risk or choose a lottery choice corresponding to each case. This simple rating scale allows researchers to quickly capture an individual's risk preferences in a quantitative format, making it easy to analyze and compare responses across different groups and contexts. An example of this risk preference elicitation method can be found in Table 4.

Table 4. Example Question from Dohmen et al. [84]

How do you see yourself: are you generally a person who is fully prepared to take risks or do you try to avoid taking risks? *(Please tick a box on the scale, where the value 0 means: 'not at all willing to take risk's and the value 10 means: 'very willing to take risk's.)*	☐ 0 (not at all willing to take risks)
	☐ 1
	☐ 2
	☐ 3
	☐ 4
	☐ 5
	☐ 6

	☐ 7
	☐ 8
	☐ 9
	☐ 10 (very willing to take risks)

 All of these methods allow researchers to estimate the risk preferences of an individual. Lottery choices, often utilized by economists, can be integrated into data collection instruments, rendering them as quantifiable measures aligned with the utility function construct of risk preference. This adaptability, as Eckel [36] notes, also contributes to the growing preference for such data collection instruments alongside their simplicity, ease of understanding for larger crowds, and inexpensive nature.

3.2. Risk perception elicitation

Understanding individual's perceptions of risk is crucial for various reasons, including informing decision-making processes, shaping public policies, and designing interventions to increase understanding of risk. Risk perceptions of individuals are measured by asking the individuals how they perceive and evaluate various. These risk perceptions are commonly measured through the data collection instruments using Likert scale questions. Participants may be asked to rate the perceived risk of particular hazards, events, or activities using Likert scales or other rating systems. These instruments may also include questions about perceived severity, controllability, familiarity, and trust in authorities or institutions managing that risk to understand the context within which the respondent is making the risk perception valuation. This comprehensive approach allows researchers to capture a broad spectrum of risk perceptions and provides valuable insights into individual's attitudes and behaviors regarding risk.

Likert-scale questions are a common method of assessing risk perceptions across various domains. Typically, participants are presented with statements regarding specific topics or subjects and are asked to indicate their level of agreement or disagreement using a 5-point or 7-point Likert scale. The Likert scale typically goes from "Strongly disagree" to "Strongly agree" with "Neither agree nor disagree" as a neutral point, as shown in the example in Table 6. The use of a "scale" enables individuals to express nuanced views, providing valuable insights into their perceptions of risk. The simplicity of Likert-scale questions makes them accessible to diverse researchers and a wide range of participants.

Table 5. Example Likert-style question [146]

	☐ 1. Extremely Unlikely
How likely is it that X will occur/ [you will do X] this year where you live?	☐ 2. Unlikely
	☐ 3. Neither Likely nor Unlikely
	☐ 4. Likely
	☐ 5. Extremely Unlikely

Another risk perception measurement data collection instrument is the DOSPERT (DOmain-SPEcific Risk-Taking scale) [12] to measure risk perceptions across various domains of life. It

emphasizes the focus on assessing risk perceptions in specific areas rather than a general risk perception. The scale consists of 30 items divided into six domains: Financial, Health/Safety, Recreational, Ethical, Social, and Gambling. Each domain consists of five items that represent different risk-taking scenarios. For example, the statements in the DOSPERT scale ask the participants to rate the likelihood of engaging in an activity or behavior such as "Investing 5% of your annual income in a very speculative stock." and "Driving a car without wearing a seat belt." The complete list of questions in DOSPERT is provided in Appendix A.

The DOSPERT scale is designed to recognize that people may exhibit varied risk perception depending on the context, while other methods can also be adapted to be domain specific the DOSPERT questions are prewritten for the six identified domains. The scale, as shown in Table 6, provides more nuanced insights into an individual's risk views.

Table 6. DOSPERT scale for risk taking and risk perception.

Option	Risk taking	Risk perception
1	Extremely Unlikely	Not at all Risky
2	Moderately Unlikely	Slightly Risky
3	Somewhat Unlikely	Somewhat Risky
4	Not sure	Moderately Risky
5	Somewhat Likely	Risky
6	Moderately Likely	Very Risky
7	Extremely Likely	Extremely Risky

Focus groups and interviews are other modes that provide insights into how individuals perceive and interpret risks. The participant's beliefs, perceptions and emotions can be explored relative to a specific risk or a particular event, allowing for a richer understanding of the factors shaping the risk perception. Focus group discussions allow for a broad exploration and a deep understanding of the topic, especially when the intent is to gather general themes and ideas on topics not yet well studied. Focus groups are particularly useful when no existing research can provide the basic information and the theoretical basis may be unclear; they are an ideal way to generate new ideas that will be relevant for subsequent larger-scale studies, surveys, and future research ([72], [97]).

The psychometric paradigm is another popular method, which involves using factor analysis to identify underlying dimensions of risk perception of people with respect to hazards [125]. This framework captures both cognitive and emotional aspects of how individuals perceive risk. Research in the psychometric paradigm has demonstrated that emotional reactions play a crucial role in shaping an individual's perceptions of risk, impacting how they evaluate physical, environmental, and material hazards beyond their objective outcomes. According to this framework, individuals assess the riskiness of a hazard by considering a combination of various risk characteristics such as controllability, severity, and familiarity, among others. Individuals are asked to rate the possible hazards on a 5-point Likert scale for associated risk characteristics such as knowledge of risk to those who are exposed, control over risk, severity of the incident, and number of people killed from the incident [118]. By analyzing the patterns, researchers can

identify how an individual's risk judgments are influenced by different hazard characteristics and contribute to more effective risk communication and management strategies.

Visual aids help in eliciting risk perceptions by providing a structured, intuitive way for individuals to evaluate and compare potential risks. The participants are presented with visual representations of risks and are asked to interpret and respond to various scenarios. Graphical representations, such as risk matrices, decision trees, visual aids can facilitate informed decision-making [49]. For example, participants are presented with categories such as "low probability/low impact" to high probability/ high impact" where individuals place risks such as 'hazard', 'health issue', or 'driving' within these categories based on their perceived likelihood and potential consequences [87]. Participants then interpret these placements by assessing the seriousness and urgency of each risk, considering how the combination of probability and impact informs their judgment on which risks require immediate attention or mitigation efforts. This interpretation process helps to reveal the participant's subjective perceptions of risk severity and prioritization, as well as their underlying attitudes toward different types of risks.

The approaches and methods discussed in this section offer insights into an individual's risk preferences and perceptions. By employing these diverse techniques, researchers can gather comprehensive data that reflects the complexity of human risk attitudes, enabling more accurate predictions and tailored interventions. This holistic approach to risk elicitation is crucial for developing effective strategies in fields such as public policy, business, and community resilience planning. However, when assessing risk preferences for more than a single individual, especially in situations with pooled resources and shared outcomes, such as a group or organization, the dynamics may be entirely different. It becomes critical to understand collective attitudes, preferences of group members towards risk, and how the decision is going to affect the entire group. We will discuss the elicitation of group risk preferences in the following section.

4. Group and community risk preferences

Individual risk preferences pertain to an individual's tolerance for risk, for themselves, and in situations that impact themselves and/or others. However, since people are inherently social beings, many activities and decisions involve multiple individuals, even when there is a single representative decision-maker, which shifts the focus to group behavior. Group risk preferences extend the study of risk preferences over uncertain outcomes beyond the individual to collective entities such as teams, households, organizations, and more broadly into communities or societies.

4.1. Group risk preferences

Relatively few studies focus on group risk preferences, and those that do typically address only small groups, exploring concepts such as social preferences, collective decision-making, and risk-sharing mechanisms ([38], [56], [121], [138]). Studies centered on methods from sociology, public health, economics, and environmental science have examined how group dynamics, social norms, and institutional factors influence risk perceptions and decision-making at the community level.

Research confirms that groups tend to make decisions that differ from those of individuals [20]. Individuals tend to match with others who have similar risk preferences within their networks, particularly in informal settings such as family or social groups, reflecting a preference for interacting with those who share similar risk attitudes [104]. This has also been studied through investigations of how social influence, peer effects, and conformity play a role in the formation of group risk preferences. Social identity theory and social learning theory have suggested that social interactions and norms influence one's risk preferences, leading to convergence or divergence of preferences as part of the discussion around compliance and conformity within groups [24]. Smaller group risk preferences have been studied against individuals in lottery valuation experiments in the economic context and identified that the average group is more risk averse than an individual ([89], [121]). However, Knippenberg et al. noted that group risk preferences are neither risk-seeking nor risk-averse; rather the preference depends on the problem the group is facing [138]. Harrison et al. [56] found a significant effect of group information on elicited risk attitudes in the social setting, and subjects are significantly more risk averse when they know the risk preferences of other group members. Existing research has primarily examined smaller groups (e.g., fewer than five members within the group). However, the shift in people's risk attitudes when making decisions for themselves versus for others versus a larger community, especially where the decisions could impact a broader population, remains largely unexplored.

Surrogate decision making is one area of study popular in the health sciences, which has also investigated risk preferences when other individuals are involved. Surrogate decision-making is when someone (Person A) makes a decision on behalf of another person (Person B) for something impacting that other person (Person B) [151]. Recent research has focused on one's accuracy within surrogate decision-making specifically in the healthcare domain, where health decisions are critical, especially for an aging population ([71], [122], [117]) or in the financial sector, where

financial experts take investment decisions on behalf of their clients or govern one's financial affairs ([39], [151], [149]). However, surrogate decision making has been underexplored for larger groups or communities where decisions impact a significantly larger population.

4.2. Measuring group risk preferences

Measuring group risk preferences is more complex than measuring individual risk preferences, requiring a multifaceted interdisciplinary perspective. Researchers have employed various approaches, including aggregation methods, experimental designs, and social influence analyses, to compare individual and group risk preferences.

Aggregation can be achieved through simple and straightforward mathematical approaches. It has an underlying assumption that the preferences of the group can be estimated from the distribution of the individual risk preferences [1]. The distribution refers to the spread and variability of individual risk preferences within the group. It encompasses not only the statistical metrics such as mean, median, and variance as well as how well the preferences are distributed across the options or categories. For example, individual risk preferences can be aggregated through simple averaging or summation of individual responses. In a survey-based study, researchers may calculate the sum, mean or median risk preference score across all participants in a group to achieve a group consensus ([46], [68] , [83], [130]). Although this approach provides the ease to estimate group risk preferences, the heterogeneity within the group may be overlooked and might fail to capture the nuances. It also makes the inherent assumption that all responses are equally weighted in the decision-making process.

Weighted aggregation is another method that can reveal the relative importance or influence of each individual's preference within the larger group. This method assigns weights to responses of certain individuals with the group risk preferences obtained either from weighted averaging or weighted summation [35]. For example, in households, the preference of the head of the household might be weighted greater than other household members or in an organization, the risk preferences of senior leaders or key stakeholders may carry more weight in determining the group's preferences. In the context of community resilience planning, weighted aggregation can ensure that the vulnerable and marginal populations are represented. For example, greater weights can be assigned to people who are living in the flood-prone zone of the community than the others who are not when developing a flood mitigation plan. Weighted aggregation allows for a more nuanced understanding of group risk preferences by accounting for variations in individual influence [8].

Another statistical method, latent class analysis, is a technique that allows researchers to identify subgroups with similar characteristics and patterns using observed variables from among the larger group [53]. In identifying group risk preferences, this method can assist in identifying subgroups with similar risk preferences such that these latent classes (subgroups) can help analyze the underlying heterogeneity of risk preferences across the group ([29], [139]).

Aggregating individual risk preferences to estimate group risk preferences is a complex process that requires careful consideration of methodological approaches and theoretical frameworks. While simple aggregating methods provide a convenient way to estimate group preferences,

more sophisticated techniques such as weighted aggregate and latent class analysis offer insights into the dynamics of group decision-making and the emergence of collective preferences. By combining multiple methods and perspectives, researchers can gain a deeper understanding of how individual risk preferences manifest at the group level and influence community outcomes.

4.3. Community risk preferences

Furthering the group risk preferences to a larger scale, e.g., organization or community, is essential for various efforts, the primary among which is community resilience planning. It enables tailored interventions that reflect the collective risk tolerance and perceptions of the organization or community, ensuring more resilient and adaptive responses to potential threats.

In larger groups, such as organizations, effective risk management mechanisms are essential for navigating uncertainty and crises. Risk perceptions and preferences are often formalized into risk management frameworks. Enterprise risk management frameworks such as ISO 31000 [62] or the committee of sponsoring organizations of the Treadway Committee (COSO) provide structured approaches to assess and address risks comprehensively. These frameworks enable organizations to identify potential risks, evaluate their possible impacts, and implement strategies to mitigate or manage them effectively. The Protective Action Decision Model (PADM) [78] is another valuable framework that helps organizations and, on a larger scale – communities understand how individuals and groups make decisions during crises or emergencies. By analyzing factors such as threat severity, uncertainty, and the efficacy of protective actions, the PADM guides organizations in developing proactive and adaptive response strategies. The risk preferences provide a basis for the decision-making of a protective action. We can combine these with other situational factors to predict the behavioral response. Hence, knowledge of risk preferences and perceptions of all the stake holders for various threats would enable and equip the community with effective resilience measures.

The frameworks serve to integrate these diverse preferences and perceptions of individual stakeholders into the decision-making process, ensuring that responses to risks are well-informed and aligned with organizational goals in addition to creating more acceptable protective action plans. By incorporating evaluation mechanisms discussed earlier in this article, organizations can map stakeholder's risk attitudes and integrate them seamlessly into the decision-making process. This integration allows for the comprehensive evaluation of risk treatment options and the development of effective mitigation strategies tailored to specific crises or hazards.

Additionally, assessing community risk preferences helps in fostering social cohesion and trust, as decisions are made with a comprehensive understanding of community concerns and priorities [54]. This approach supports better preparedness, response, and recovery strategies, ultimately enhancing overall community resilience. There are a few key areas where community risk preferences have been explored to date.

Risk perception is one of the important factors affecting preparedness behavior towards disasters [13]. Disaster risk perception investigates the community's perception and response to various hazards and threats by examining past experiences, preparedness, socio-economic status, belief,

trust, and other psychological characteristics ([25], [77], [78], [83], [101]). Several works utilize a mixed methods strategy, which includes both quantitative surveys and qualitative interviews to understand community risk preferences ([25], [83]).

Collective decision-making can explore how the community makes decisions under uncertainty and risk [95]. It is a process in which each person has an opportunity to influence and decide on their work and group tasks [20]. Individuals express their preferences and beliefs on an issue to reach a single decision [87]. Collective decision-making can investigate mechanisms for how individuals make decisions for their community, consensus building, governance, and community-based approach to risk management ([102], [138]).

Environment and health risk management often look at community risk preferences concerning health hazards, infectious diseases, and environmental hazards such as pollution and climate change. Studies try to assess the community's attitudes towards environmental risks, preferences for mitigation measures, including community participation in decision-making through various methods as mentioned in the article, along with the factors related to risk such as probability of the hazard and other psychological factors ([63], [66], [99]) and explore communication and risk strategies, informed decision-making, and risk reduction behaviors [27].

Several researchers have highlighted the need for better methods, as current methods often lack the robustness and flexibility needed to accurately capture the complex dynamics of diverse groups. Bang [8] suggests that simple averaging may not suffice, given the complexity of group dynamics. Instead, more sophisticated approaches that consider the interactions and dependencies among individuals within a group are necessary. For instance, deliberative processes [117], where group members discuss and negotiate their preferences, could provide a more accurate reflection of community risk preferences. However, these methods are still in their infancy and require further development and validation. Additional research is essential to create more detailed and adaptable aggregation methods that can better inform decision-making in community resilience planning and other large-scale applications.

The findings from previous research indicate that additional exploration is needed on how group risk preferences diverge from individual preferences. This distinction is pivotal for grasping the intricacies of collective decision-making and effectively managing risks that affect communities, especially in community resilience planning. However, aggregation methods for estimating group risk preferences are not well developed and, in most cases, still depend upon accurately measuring individual risk preferences. Exploring the emergence of group risk preferences from individual risk preferences has been relatively limited, except for a few methods described earlier in this section. There is a need for researchers to establish robust methods to derive group risk preferences from individual data. Additionally, it's important to explore the processes by which groups converge on a single risk preference, which is a fundamentally different approach than mere mathematical aggregation. This involves understanding the social, psychological, and communicative processes that lead to a shared group risk preference, which may differ significantly from the simple mathematical combination of individual preferences; however, there is space to also look at processes by which groups come to a single risk preference, which is different from aggregation completely.

5. Summary and future research

Understanding risk behavior is essential for effective decision-making across domains. Risk preferences and perceptions are crucial components of decision-making processes, especially in community resilience planning. Individual risk preferences reflect how a person is inclined to handle uncertainty and risk, influencing their decisions in areas such as finance, health, and public policy. Researchers have developed a range of methods to evaluate risk preferences and perceptions. Risk preference assessment often employs techniques such as incentivized games, which simulate real-world risk scenarios to observe participant's choices and behaviors. These games, along with surveys and experimental tasks, provide insights into how individuals respond to uncertainty and potential outcomes. Additionally, risk perception evaluation involves capturing subjective attitudes through questionnaires and structured interviews, helping to reveal how people assess and interpret risks. By integrating these diverse evaluation methods, researchers can gain a comprehensive view of individual risk behaviors, ultimately providing valuable insights into individual preferences.

The aggregation of individual risk preferences into group or community risk preferences, however, is an area that has not received as much attention. The few studies that do exist often focus on small groups or specific contexts, leaving a gap in understanding how to effectively aggregate individual preferences to represent larger community or group preferences. Traditional aggregation methods, such as averaging individual risk preferences, may not adequately capture the interactions and dynamics within groups. These methods often fall short of reflecting the true nature of group decision-making processes, which are influenced by various factors such as social dynamics, collective goals, and group interactions.

As much as group risk preferences highlight the dynamics of collective decision-making on larger scales, particularly at the community level, the measurement of risk preferences remains underexplored. There is a significant gap in research regarding how to measure community-level risk preferences. Quantifying these preferences at a community level is crucial, as it can provide a more accurate understanding of how communities as a whole respond to risk.

As communities increasingly face collective risks, such as climate and weather extremes, it is imperative to refine our understanding of how group risk preferences are measured, as well as how they are determined and expressed. The lack of research in this area is particularly evident in community resilience planning. Understanding community risk preferences is vital for developing effective disaster preparedness, response, and recovery strategies. Communities must make collective decisions about resource allocation, risk mitigation, and emergency response, all of which depend on the aggregated risk preferences of the members of the community. Without robust methods to aggregate individual preferences, policymakers and planners may struggle to design interventions that genuinely reflect the community's risk tolerance and priorities. By utilizing data collection instruments or choice experiments, we can investigate the differences between individual and group risk preferences while also forming the groundwork for studying aggregation methods. Considering the growing number of hazards impacting communities each year, it is imperative for researchers to address this gap in understanding community risk preferences.

While there is growing recognition of the importance of understanding how communities perceive risks collectively, there is still much to explore. Future research could focus on developing and refining methods to accurately measure group risk perception, as well as exploring the dynamics of how these perceptions are formed and influenced by various factors such as social networks, media, and cultural contexts.

Additionally, further studies could investigate the impact of group risk perception on the effectiveness of resilience strategies, including how these perceptions affect community participation in resilience-building activities and the adoption of protective behaviors. Exploring the interplay between individual and group perceptions could also provide valuable insights into tailoring communication and intervention strategies to enhance community resilience. Overall, more empirical research is needed to better understand the role of group risk perception in shaping resilience planning and to inform the development of policies and practices that strengthen community preparedness and response to potential hazards.

Limitations:

The focus of this NIST Special Publication is to provide an overview of these methods, highlighting their application in understanding risk behavior and their implications for decision-making processes. Thus, measuring or predicting risk is beyond the current scope. This is not an extensive review of all the available methods for eliciting risk preferences and perceptions. Rather, we aim to highlight some of the most popular and widely used methods and tools in evaluating and gauging risk preferences and perceptions. By integrating which, researchers can gain a comprehensive view of individual and group risk behaviors, ultimately enhancing strategies for managing uncertainty. This overview serves those interested in exploring the methods and applications of risk preference and perception elicitation and addressing the highlighted research gap.

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Appendix A. Domain-Specific Risk-Taking (DOSPERT)

The DOSPERT scale consists of 30 items divided into six domains: Financial (F), Health/Safety (H/S), Recreational (R), Ethical (E), Social and Gambling (S). For each of the questions listed below, the participant is asked to indicate the likelihood of engaging in the described activity or behavior, between a range from extremely likely to extremely unlikely. The complete set of questions in DOSPERT is as follows:

1. Admitting that your tastes are different from those of a friend. (S)

2. Going camping in the wilderness. (R)

3. Betting a day's income at the horse races. (F)

4. Investing 10% of your annual income in a moderate growth mutual fund. (F)

5. Drinking heavily at a social function. (H/S)

6. Taking some questionable deductions on your income tax return. (E)

7. Disagreeing with an authority figure on a major issue. (S)

8. Betting a day's income at a high-stake poker game. (F)

9. Having an affair with a married man/woman. (E)

10. Passing off somebody else's work as your own. (E)

11. Going down a ski run that is beyond your ability. (R)

12. Investing 5% of your annual income in a very speculative stock. (F)

13. Going whitewater rafting at high water in the spring. (R)

14. Betting a day's income on the outcome of a sporting event (F)

15. Engaging in unprotected sex. (H/S)

16. Revealing a friend's secret to someone else. (E)

17. Driving a car without wearing a seat belt. (H/S)

18. Investing 10% of your annual income in a new business venture. (F)

19. Taking a skydiving class. (R)

20. Riding a motorcycle without a helmet. (H/S)

21. Choosing a career that you truly enjoy over a more secure one.

22. Speaking your mind about an unpopular issue in a meeting at work. (S)

23. Sunbathing without sunscreen. (H/S)

24. Bungee jumping off a tall bridge. (R)

25. Piloting a small plane. (R)

26. Walking home alone at night in an unsafe area of town. (H/S)

27. Moving to a city far away from your extended family. (S)

28. Starting a new career in your mid-thirties. (S)

29. Leaving your young children alone at home while running an errand. (E)

30. Not returning a wallet you found that contains $200. (E)

Note. E = Ethical, F = Financial, H/S = Health/Safety, R = Recreational, and S = Social.