FAIRNESS AND EQUITY IN SOCIETAL DECISION ANALYSIS

L. ROBIN KELLER
YITONG WANG
The Paul Merage School of Business, University of California Irvine, Irvine, California

TIANJUN FENG
Fudan University, School of Management, Shanghai, China

Imagine you divide three cookies between your two children, five-year-old Jack and two-year-old Jill. You might give Jack two cookies and Jill one cookie. But, then Jill will claim that this division is unfair, and will remain unconvinced even when you say that Jack is older and bigger and thus needs (and deserves) more food.

In such a parental role, you may decide to give equal cookie allocations in the future, ignoring arguably good reasons for giving an unequal allocation. Such an equal allocation is particularly appealing when the recipients all know what each person was given and have the opportunity to express their feelings about their allocation. But, sometimes, an unequal distribution will seem to be the most fair and equitable, given the special features of the situation. For example, whenever there is a single undividable item, such as a family heirloom, which needs to be somehow allocated, the resulting distribution will be unequal, but a fair process may be used to determine the allocation.

Just as it is important to consider fairness in making allocations within a family, fairness plays an important role in making societal decisions, such as where to locate hazardous facilities or how to apportion benefits and costs among different parties. In the operations research literature, fairness and equity are often used interchangeably, usually referring to perceptions of the appropriateness of allocations of risks, benefits, and costs (or of the allocation process). A variety of social science domains investigate such allocations, and use a variety of terms to define specific types of fairness (such as *procedural* justice). The aim of this article is to focus primarily on how decision analysts and behavioral decision theorists (within the operations research community) have examined fairness, and provide some introduction and references to coverage in other disciplines. The section titled "Levels of Fairness Investigations" describes different levels of fairness investigations. The section titled "Fairness Factors and Issues to Consider in Societal Decision Models" presents fairness factors and issues to consider in constructing societal decision models. And the section titled "Decision Scenarios Involving Fairness and Experimental Results" presents some examples of decision scenarios involving fairness and experimental results for those scenarios.

LEVELS OF FAIRNESS INVESTIGATIONS

Fairness or equity can be examined from different perspectives. We present some of these below and provide some very brief examples of ways of looking at fairness at each of these levels.

To an Individual

Is it fair to pay a person less because he is single and has no family responsibilities? Is it fair to give priority to admitting a college student from a historically underrepresented racial or ethnic group? Is it fair to charge a customer more for an umbrella on the day it rains? Is it fair to pay a firefighter more than an office manager, since the firefighter faces more job safety risks?

Kahneman *et al*. [1,2] discuss different conditions under which an allocation of a cost or a benefit to an individual is seen as fair, and report results of a survey of the general (Canadian) public about scenarios such as fair pay and fair prices. In a laboratory experiment, Mellers [3] examines what fairness principles appear to be used by

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experimental subjects in allocating salaries or taxes. When focusing on fairness to an individual, there still are usually implicit comparisons with what others in similar situations will receive or comparisons with the process that is used with others.

Within Families

How can heirs fairly decide which heir should get the sentimentally important stamp collection? During a divorce case, does the wife get a better deal than the husband, or is the settlement fair?

Pratt and Zeckhauser [4] describe how to fairly divide a number of silver heirlooms among heirs, where each heir's preferences for objects are represented by his or her utility function, then allocations to different heirs are made as they would be in a market for probability shares in the items, assuming each heir has an equal budget for making purchases and the item prices are the market-clearing equilibrium prices in a second-price auction.

In a married couple, each person brings some inputs to their marriage and receives benefits from the marriage, in some proportion to their inputs. The Walster *et al*. [5] book on equity theory addresses issues such as equity within a marriage (and in other settings).

Between Interested Entities/Parties

How fair is the $2/h raise the university gave its lowest paid workers and the salary cut it gave other workers? How much of a movie's revenue should go to the actors versus the producers?

In cases involving disputes over revenue sharing between joint enterprise partners or negotiations in real estate transactions, involved parties (i.e., people, business, trade organizations, etc.) care about the fairness of the process and the eventual allocation. There is a large body of mathematical research dealing with this type of situation, which is called the *Cake-cutting problem* [6,7]. In this problem, "cake" could mean any desirable goods or benefits and "cutting" means the methods people use to divide them. The basic question—how to fairly cut a cake—represents many issues involving multiple interested groups that want to share an entity fairly. Robertson and Webb [6] focus on three main issues in their mathematical survey of the cake-cutting problem: (i) the existence of a solution; (ii) the procedure to construct the solution; and (iii) what are the properties of the procedure to the solution. Brams and Taylor [7] address fair division from the cake-cutting problem to dispute resolution. Also see Raiffa's [8] book on negotiation methods and Camerer and Thaler [9] for related game theoretic experiments and results. Hoffman and Spitzer [10] examined participants' concepts of distributive justice in a laboratory experiment and Margolis' [11] book addresses how one person allocates outcomes to another in either a selfish or an altruistic way.

Within an Organization

Considering how much work I did on a project, did I get a fair amount of recognition for my contribution? How fair is the personnel process at my company? How fairly did my boss treat me during the last round of bonus allocations?

Organizational behavior researchers examine workplace fairness in terms of distributive justice, procedural justice, and interactional justice, and then examine the effects of perceived justice on behaviors, such as workplace revenge. Distributive justice refers to whether the outcome in a case is seen as fair, given the inputs [12,13]. Procedural justice focuses on the process by which outcomes are distributed [14]. Interactional justice is concerned primarily with how people are treated [15]. When observers within an organization see how others are treated they may want to believe that people get what they deserve and that there is a "just world" [16,17].

Comparing Within a Region or Nation

How fair is the distribution of land ownership or wealth in a country? How should we examine fairness of electric utility pricing within a region or nation? Do underprivileged groups face more environmental risks?

Rawls [18] discussed the theoretical notion of imagining oneself behind a veil of ignorance about which location in a society would ultimately be held by that person. Then, a person can consider what would be a fair distribution across the society, in ignorance of whether that person's ultimate fate would end up as being in a rich or a poor position. He then proposed that in the "original position" behind the veil a person would adopt a maximin strategy, which would maximize the position of the least well-off person (who has the minimum allocation). Economist John Harsanyi had a similar discussion in his work on the social welfare theory of utilitarianism. Suppes [19] also examined the distributive justice of income inequality. Zajac [20,21] examined fairness in public utility regulations. Zimmerman and colleagues [22–25] empirically examined the fairness of actual distributions of environmental risks, particularly to people in poorer areas, calling this field "environmental justice."

Comparing People Across Nations

How far apart are the wealthy and the poor in one country versus another? Do the same concepts of fairness apply in the United States and in China?

One can graph the distribution of family income within one country and compare it with the distribution in other countries. For a group of N families, the graph called a *Lorenz curve* plots the cumulative family income for the poorest x families on the y-axis against the number of families arranged on the x-axis from the poorest family (#1) to the richest family (#N). If all N families have the same income, which is presumably most fair, then the Lorenz curve is the straight 45° line. If many families have low incomes and only a few have high incomes, the Lorenz curve is convex and falls far below the straight 45° line. A popular way to make a comparison of the distribution in different countries is to use the Gini index, which is calculated from the Lorenz curve by computing the ratio of the area between a country's Lorenz curve and the 45° line divided by the entire triangular area under the 45° line. Therefore, a higher Gini index indicates more inequality. The scores for different countries and an explanation of the calculation of the index are at https://www.cia.gov/library/publications/the-world-factbook/fields/2172.html.

There are differences in fairness perceptions between cultures. In some countries, the closest word to the English word fairness may be justice or balance. Interestingly, in the Canadian public survey [2], respondents answered on a bipolar scale, anchored by acceptable and unfair. For many in Western countries, these two concepts may indeed be two ends of a single scale. Certainly, when a child complains about unfairness in cookie allocations, it usually also means the allocation is unacceptable. However, from some other perspectives, such as those of Chinese, there may be two different dimensions: unfair to fair versus unacceptable to acceptable; see Bian and Keller [26, p. 317]. Bian and Keller found that Chinese [27] agreed with Americans [28] on fairness judgments involving societal risks, but disagreed on the best actions to take. In some cases, where there was a chance that a large group would die, the Americans would take the action that they saw as fair, but Chinese would not. In interviews with Chinese [27], it appeared that when the cultural value of treating everyone equally was in conflict with the value of preventing the extinction of the whole community, Chinese would take actions to avoid extinction of the community; see also Keller *et al*. [29] for additional details on these studies on "risk equity," which involved scenarios with probability distributions over health or safety outcomes.

FAIRNESS FACTORS AND ISSUES TO CONSIDER IN SOCIETAL DECISION MODELS

When I ask you if a particular allocation or transaction process is fair, you will likely respond, "it depends." Perceptions of fairness can depend on a variety of current and preexisting factors and issues. Fairness is also in the "eye of the beholder," so a person from one culture or one point of view may see unfairness when another person sees fairness. In the cookie example, Jack may see it as fair that he, the older child, gets two cookies, but Jill sees it as unfair.

While a parent may use an equal division of cookies among children, in many cases equal distribution is not feasible or prudent. A good introduction to different concepts of fair division is in Yaari and Bar-Hillel's [30] paper on dividing justly. They identified six categories of factors which "provide a possible justification for departure from equality," including the following:

1. differences in needs;
2. differences in tastes, or in the capacity to enjoy various goods;
3. differences in beliefs;
4. differences in endowments;
5. differences in effort, in productivity, or in contribution;
6. differences in rights or in legitimate claims.

When you are in charge of a societal decision analysis, which involves different outcomes (such as monetary benefits or costs, health and safety risks, etc.) to different people, you may want to ask yourself a number of questions to determine which factors should be considered in your decision process. Examples of such societal decisions are selecting a hazardous waste processing site in a region, choosing where to send emergency personnel in a major disaster, and budget allocation between elementary and middle schools. A few of the possible questions to ask before constructing your decision analysis model and process are listed below.

From the Perspective of an Outside Society Member, Does it Matter What the Different Parties Get?

Suppose an outsider does not receive any part of an allocation. Would that person care how the allocation is divided among those who receive an allocation? In such a case, the societal decision maker may wish to spread the allocation more fairly even if those affected do not know or do not care about what others get. See Lichtenstein *et al*. [31] and Wagenaar *et al*. [32] for discussions of the perspective of the societal decision maker and for some stylized societal decision scenarios. One thing that may matter to the public or the decision maker is if the decision maker takes an action to give people unequal allocations or if the decision maker passively allows already occurring inequalities to remain.

Do the Different Affected Parties Care What Others Get?

Direct observation of others (such as watching children like Jack and Jill) or self-introspection will likely lead to the answer "yes." Yet, simple economic models often assume that a person merely cares about his own allocation. This makes it appear that economists tend not to be concerned about a person being selfish (since that is what such models would expect to occur) and tend to be baffled that a person would be altruistic. Indeed, they may work hard to explain altruistic behavior within the scope of such models by assuming that the altruism somehow helps the individual. For a different point of view, see the books by Margolis [11] on *Selfishness, Altruism, and Rationality* and Robert Frank [33] on *Choosing the Right Pond* for economic discussions in which people care about what others get.

Do the Different Parties Know What Others Get? Do They Know What Different Parties Started Out with or Did to "Deserve" Their Outcomes?

Often, fairness disputes may develop because affected parties do not know all the historical or preceding factors that may support an unequal allocation to one person in comparison with another. A raise may make up for not getting a raise in the last round of merit reviews, for example. See Mellers and Baron's edited book [34], *Psychological Perspectives on Justice,* for discussion of various components of fairness perception.

If the different parties care about what others get, and know what others get, then you may want your decision analysis model to keep track of allocation differences between neighbors or others who compare themselves, since such differences might be important. In some cases, you may choose to reveal the

allocation process and outcomes for all parties, even if the parties would not normally have been able to observe these.

Do the Different Parties Prefer that They Get the Same Outcome at the Same Time or, in Contrast, Do They Prefer That They Get the Outcome at Different Times?

The concept of common fate equity refers to situations where a set of people would like to experience the same "common" outcome simultaneously, even if it is a bad outcome. They prefer sharing a common fate over experiencing common fate inequity, where they would experience a bad (or good) outcome separately.

Parents of young children may choose to not fly together, so that they do not share the common fate of both dying together in the same airplane crash. Companies often have rules that top executives cannot fly together for a similar reason. In such cases, these rules avoid the parents or executives experiencing the common fate of dying from the same risky event. Sadly, such common fate events, though rare, do occur, such as the crash of the presidential plane carrying President Lech Kaczynski of Poland and 95 others including his wife, lawmakers, military commanders, priests, and others on April 10, 2010.

An axiom of preference for *common fate inequity* captures the preference to avoid common fates in decision analysis models. In other situations, a common fate will be preferred. See Fishburn's [35] common fate equity axiom E4 and a newer treatment of a preference for "shared destinies" in Ref. 36. A decision scenario illustrating common fate preference among experiment participants [27,28] is in the section titled "Decision Scenarios Involving Fairness and Experimental Results" below.

Is It Possible for Parties to Trade Their Allocations to Achieve Better Outcomes?

Sometimes it is possible to adjust allocations among parties enough that they will see the final allocation as fair. One concept of fairness in this case is an *envy-free* allocation, one where no one envies what any other person has, and would not want to switch his own allocation for another's allocation. Keller and Sarin [28] present an envy-free risk-benefit model. However, there may be no envy-free allocation possible. In such cases, the societal decision maker must make difficult trade-offs, especially when health and safety risks are involved and there are shortages of life-saving resources (such as donated kidneys for kidney transplant surgeries). Calabresi and Bobbitt [37] identify four approaches in such "tragic choices": pure market, accountable political, lottery (such as a military draft), and customary or evolutionary mechanisms.

Should Fairness to Future Generations be Considered?

When societal decisions may have effects on future generations, the fairness of the outcomes to those currently living compared to future generations may need to be considered. When called for, economists and decision analysts build considerations of intergenerational effects into their models. For example, Morton *et al*. [38] created a multiple objective decision analysis model to make recommendations to the UK government on what should be done with accumulating radioactive waste. One of their objectives was reducing "burden on future generations," which was an influential objective when the decision of deep disposal of waste would be the preferred option over other storage options.

DECISION SCENARIOS INVOLVING FAIRNESS AND EXPERIMENTAL RESULTS

In this section, we give examples of decision scenarios involving allocations between people (of healthy foods or safety risks) and show what survey respondents chose.

Healthy Fruit Allocation Scenario

Yaari and Bar-Hillel [30] conducted an experimental survey to examine what choices participants would make in a number of scenarios where allocations across people would be made. They then examined the predominant choice pattern to see how it aligns with different concepts of fairness. Here is their first question, from Ref. 30:

> A shipment containing 12 grapefruit and 12 avocados is to be distributed between Jones and Smith. The following information is given, and is also known to the two recipients:
>
> - Doctors have determined that Jones's metabolism is such that his body derives 100 ml of vitamin F from each grapefruit consumed, while it derives no vitamin F whatsoever from avocado.
> - Doctors have also determined that Smith's metabolism is such that his body derives 50 ml of vitamin F from each grapefruit consumed and also from each avocado consumed.
> - Both persons, Jones and Smith, are interested in the consumption of grapefruit and/or avocados only insofar as such consumption provides vitamin F—and the more the better. All the other traits of the two fruits (such as taste, calorie content, etc.) are of no consequence to them.
> - No trades can be made after the division takes place.
>
> How should the fruits be divided between Jones and Smith if the division is to be just?

A large majority (82%) of Yaari and Bar-Hillel's 163 young adult respondents chose for Jones to have 8 grapefruits and 0 avocados (remembering that avocados did not benefit him at all) and for Smith to have 4 grapefruits and 12 avocados. Only 8% of the participants chose an equal division of six grapefruits and six avocados to each person. Therefore, in this case, the number of milligrammes of vitamin F [8×100 for Jones and $(4 \times 50) + (12 \times 50)$ for Smith] were equated on the basis of how much each person needed to eat to get the vitamin benefit, rather than the number of fruits.

Subsequent similar scenarios in Ref. 30 involve variations of needs, tastes, and beliefs. Proceeding through these examples, many subtle variations in fairness judgments are demonstrated. In societal decision analyses potentially involving similar subtle variations in fairness, it is important for decision models to keep track of such factors that would be important to the members of society for whom the decision is to be made.

Rescuer at Risk Scenario

Next, we consider the "Rescuer at Risk" scenario from an experimental survey conducted by Keller and Sarin [28] with American respondents and by Bian and Keller [27] with Chinese respondents:

> On an island within your jurisdiction, 100 miners are trapped in one location in a mine. There is a way to rescue these miners by sending a rescue team through an unused tunnel. You have dispatched a rescue team of 10 rescuers to this tunnel. The team has come upon a portion of the tunnel that is dangerous. They need to station a rescuer at this point in the tunnel for the next 10 h to listen and watch for any signs that the trapped miners send to the team. However, there is a chance that, sometime in the next 10 h, a cave-in will occur, which will be fatal to the rescuer stationed there. The rest of the tunnel is safe, so the rescuers are not at a risk in other parts of the tunnel. The team is able to communicate with you at a command post via a portable radio. The team has contacted you for your orders about what to do next. They want to know if they should station one rescuer at the key point in the tunnel for 10 h or have each rescuer take a 1-h shift. There is a 10% chance that a cave-in will occur, and only one cave-in would occur, if any.
> The rescuers will definitely be able to save the 100 miners, no matter which option is taken.
>
> **Option 1.**
>
> One rescuer does the entire 10-h shift.
>
> This rescuer has a 10% chance of death.
>
> The other nine rescuers have a 0% chance of death.
>
> **Option 2.**
>
> Each of the 10 rescuers takes a 1-h shift.
>
> Thus, each rescuer has a 1% chance of death because each would be in the tunnel one-tenth of the time, and one-tenth times 10% is 1%.

This scenario examined the *ex ante* fairness for the rescuers in doing their jobs, before the risk outcome (possible death of a rescuer) has the uncertainty resolved. Among respondents asked to indicate the fairer option, large majorities felt that Option 2, where each rescuer faced 1 h of risk, was fairer

(96% of 53 American adults, 96% of 51 young Chinese adults, and 82% of 49 middle-aged Chinese adults). For those who were asked which option would be chosen (not which is fairer), relatively large majorities chose Option 2 (83% of 53 Americans, 84% of 47 young Chinese adults, and 62% of 49 middle-aged Chinese adults).

For societal decision makers, it is often important to consider the *ex ante* risk to members of society, because society members may prefer a more equal distribution of *ex ante* risk, if feasible; see Keller *et al*. [29] for an example of a decision model that incorporates a preference for *ex ante* equity.

Miner Location Scenario

Now consider the "Miner Location" scenario from Keller and Sarin [28] with American respondents and by Bian and Keller [27] with Chinese respondents.

> On an island within your jurisdiction, 100 miners are trapped, 50 in location A and 50 in location B. Two rescue options are possible.
>
> **Option 1.**
>
> Attempt to rescue all the miners in both locations.
>
> The possible outcomes are
>
> 50% chance that none die (because the rescue operation is successful);
>
> 50% chance that all 100 die (because the rescue operation is not successful).
>
> (Considered more fair by most Americans and Chinese, chosen as the action to take by most Americans and a weak majority of young Chinese adults)
>
> **Option 2.**
>
> Attempt to rescue only the miners in one location.
>
> The possible outcomes are
>
> 50% chance that the 50 miners in location A live and the 50 miners in location B die because the rescue operation is sent to location A;
>
> 50% chance that the 50 miners in location B live and the 50 miners in location A die because the rescue operation is sent to location B.
>
> (Chosen as the action to take by a weak majority of middle-aged Chinese)

In Option 1, the miners all experience the same common fate, since either all 100 would die or all would live, so this is an *ex post* equitable option, in the sense of Fishburn's [35] common fate axiom. In the survey, a strong majority of American adults and a weak majority of young Chinese adults chose Option 1, where the miners all experience the same common fate. In contrast, a weak majority of middle-aged Chinese adults chose Option 2, which results in common fate inequity, but avoids the catastrophe of all 100 miners dying. A possible explanation for this difference in choices is that the traditional Chinese culture places more emphasis on protecting the group, as expressed in the cultural value of collectivism. (In contrast, the American culture places more emphasis on individualism.) Therefore, the middle-aged Chinese who chose Option 2 avoided the possible loss of the entire group.

For societal decision makers, it is sometimes important to consider the *ex post* risk to members of society; see Keller *et al*. [29] for an example of a decision model incorporating a preference for *ex post* equity. As illustrated in this common fate scenario, models may need to be flexible enough to be consistent with preference for equity or inequity, depending on specific contextual or cultural factors.

CONCLUSION

This article has provided a brief theoretical and empirical introduction to the examination of fairness and equity in societal decision analysis. For a more advanced discussion of "risk equity," which considers risk in scenarios with probability distributions over health or safety outcomes, see Keller *et al*. [29].

In conclusion, societal decision makers need to consider the fairness of their allocations and their allocation process. In some situations, they may want to reason normatively about which fairness principles to follow. In others, they may wish to consult with stakeholders about perceptions of fairness or

gather experimental survey data to confirm what the affected population would prefer.

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