Review of Decision-Making Theories

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Introduction

The report is a literature review of Theories on Human Decision Making. It tries to highlight crucial researches in the development of understanding human decision making. Decision making is not an easy task. Monumental decisions taken by multi-national organizations, governments, etc. affect a large diaspora of individuals. Every organization needs a framework to make right decision. There has been extensive research on how people make decision and how they should make decisions.

This report starts with a brief introduction on what decision making is and how it is done. Then it explains the various techniques which are used to arrive at a decision. Depending upon the type of problem, suitable technique is applied.

Afterwards, it talks about the most basic and important theory of decision making i.e. Rational Decision Making. Origin of the theory, its uses and limitations are explained in detail. The next theory which is explained is Expected Utility Theory. This theory is the most important theory in decision making. It merges the conceptual framework of rational decision making to more theoretical and mathematical approach. This lead to substantiate the choice being made. Although this is not an exhaustive theory and there are loopholes in it. It paved way for further improvements in decision making study. It is still applicable and is widely used. The improvements lead to development of prospect theory, sure thing principle, min-max utility theory and so on.

The problem with all these theories is that none can explain all the paradoxes and irrationalities in human decision making. If it works in one situation, it might not hold ground in other.

To create a unified theory of decision making which can explain all the paradoxes and ambiguity in decision making a new approach is being considered. It is called Quantum Decision Making. It applies the mathematical framework of Quantum Physic to cognition and decision making. It is explained in the last part of the report.

Decision Making

Information is not Knowledge

- Albert Einstein

Decision making is the idea of choosing from alternatives available. Decision making is not limited to some esoteric event in life. Every day we must make decisions, many of which doesn't have a high-risk factor or ambiguity. It simply doesn't worth to invest a lot of time in making those kinds of decisions like what to have for dinner or to attend the next class or not. But there are certain decisions which requires deliberate thinking and reasoning. While choosing a grad school one takes into considerations various factors like placement, monetary investment, quality of faculties, city etc. Here, we must make a decision which will highly affect our future. Manager's must determine the organization's goals like what products or services to offer, which supplier to choose, select new employees, decide how to allocate money. Thus, decision making is an important part of corporate life as well. There are numerous scenarios where one needs to decide judiciously, what to do.

Human Decision Making has been an extensive field of research. Many models have been developed to imitate human decision making. Another side of it is to decide which choice to make so that it will give the optimum output.

Decision Making Process

By and large a rational decision making follows the following steps:

Step 1: Define the problem

Step 2: Identify the decision criteria

Step 3: Allocate weights to the criteria

Step 4: Develop the alternatives

Step 5: Evaluate the alternatives

Step 6: Select the best alternative.

Normative Decision Theory (*What*) vs Descriptive Decision Theory (*How*)

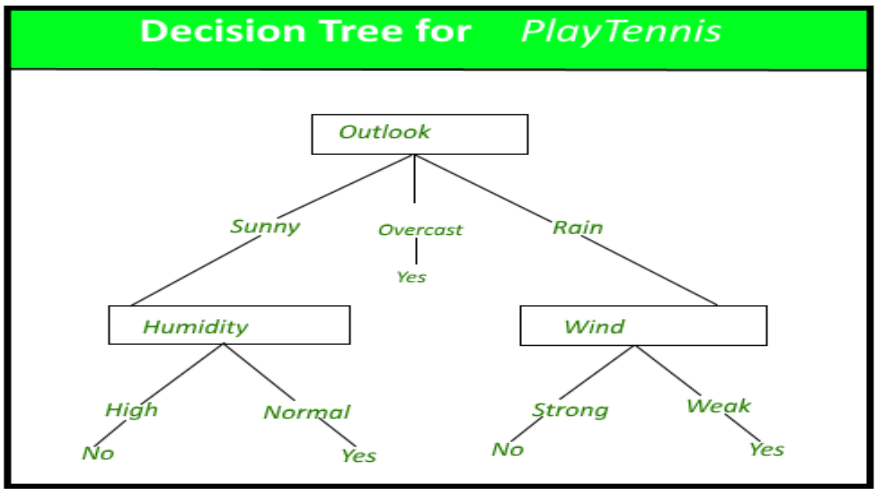
All the decision-making models can be categorised in 2 types:

1. *Normative Decision Theory*: Most of decision theory is normative or prescriptive, i.e., it is concerned with identifying the best decision to take, assuming an ideal decision maker who is fully informed, able to compute with perfect accuracy, and fully rational. It answers what should we do.
2. *Descriptive Decision Theory*: It is a rising field of study. There are several decision-making behaviours and paradoxes which cannot be explained by classical theories, like Ellsburg paradox or Allais paradox. These theories try to understand what we really end up doing.

Decision Making Techniques

There are several ways to reach the destination. It depends on the type of problem and your approach towards it, which way you would go. Similarly, there are various techniques to make a decision and it depends upon you which technique you choose. Few of the widely recognized techniques are as follows:

- **Decision making tree:** This technique helps visualize multistage decision problems while addressing uncertain outcomes. It can be useful in deciding between strategies or investment opportunities with constrained resources.



		Player II: Confess	Player II: Refuse
Player I	Confess	2,2	4,0
Player I	Refuse	0,4	3,3

- **Game Theory:** Game theory is a theoretical framework to conceive social situations among competing players and produce optimal decision-making of independent and competing actors in a strategic setting. Using game theory, real-world scenarios for such situations as pricing competition and product releases (and many more) can be laid out and their outcomes predicted.
- **Linear Programming (LP):** It involves creating and solving optimization problems with linear objective functions and linear constraints. LP is a very powerful tool that can be applied in many business situations. Steps involved in LP model:
  1. Understand the problem
  2. Identify the decision variable
  3. State the objective function as a linear combination of the decision variables.
  4. State the constraints as linear combinations of the decision variables.
  5. Identify any upper or lower bounds on the decision variables.

- **Heuristic Methods**: The study of heuristic in decision making was started by Kahnemen and Tversky in 80's. Heuristics are methods for solving problems in a quick way that delivers a result that is sufficient enough to be useful given time constraints. Investors and financial professionals use a heuristic approach to speed up analysis and investment decisions. Some examples of heuristic techniques are:
  1. Trial and error,
  2. Rule of thumb,
  3. Educated guess,
  4. Intuitive judgement, etc

  Some of the heuristic models are:

  1. Availability Heuristic,
  2. Familiarity Heuristic,
  3. Representativeness Heuristic,
  4. Satisficing, etc.

Other Decision-Making Techniques

- Multiple Criteria Decision Analysis: This technique was developed by Dr. Charles H. Kepner and Dr. Benjamin B. Tregoe. This technique provides a good compromise between intuition and analysis by using a systematic framework that evaluates options against a defined set of success criteria with adjustments for risk.

- Paired Comparison Analysis: Options are compared against one another in pairs to establish relative importance. A drawback in this technique is that little or no information is exposed that identifies the criteria supporting each alternative.
- Pro/Con: This is the age-old approach of looking at the pros and cons of two options. A key limitation is that these decision-making techniques look at only two options at a time.

- Multi-voting: This technique is used for group decisions to choose fairly between many options. It is best used to eliminate lower priority alternatives before using a more rigorous technique to finalize a decision on a smaller number of options.

- Cost/Benefit analysis: This is limited to financial decisions or can provide the data for evaluation of financial criteria in other decision-making techniques.
- Trial and Error: This approach to learning has provided the basis for decision making from our childhood. Main limitations are that consequences for decision failure should be small, and proper reflection must be done after the trial and error to ensure that correct cause/effect relationships are identified in the learning.

Rational Choice Theory

The idea that all actions is fundamentally "rational" in character and that people calculate the likely benefits of any action before proceeding to do that. It holds that individuals must anticipate the outcomes of alternative courses of action and calculate that which will be best for them. Rational individual chooses the alternative that is likely to give them the greatest satisfaction.

Rational choice theory originated during the late 18th century with the work of Cesare Beccaria. Beccaria in his work *Crime and Punishment* stated the idea of rational decision making for giving judgements to criminal proceedings. Although he didn't do much work particularly on rational decision making, his idea flourished. Before that decision making was considered constrained by social situations. The idea of individualism and minimalism made way in sociological perspective.

Abell notes that "i*t is only individuals who ultimately take actions and social actions … individual actions and social actions are optimally chosen" and "individuals' actions and social actions are entirely concerned with their own welfare"*.

Since then, the theory has been expanded upon and extended to include other perspectives. Most notable influences on RCT were of Max Weber, Adam Smith, Vilfredo Pareto and recently American and European Theorists

To make a decision with rational choice some fundamental assumptions have been made. They are as follows:

1) Completeness - All possible choices can be compared and ranked, and choices can be discrete or continuous. It means that if a person faces two choices, he will necessarily have an opinion on which he likes more. He may be indifferent, but he is never completely clueless. Also, this does not exclude the possibility that y = x i.e. equally satisfactory.

2) Non-satiation or Monotonicity – Property of non-satiation states that more of a good is better, ceteris paribus (all other things remain equal).

3) Transitivity (consistency) – Simply put if AYB and BYC, then AYC. For example - if a person prefers beer to wine, wine to tequila, then he must prefer beer to tequila.

4) Convexity – It states that a mixture of goods is more preferable to extremes. It means people like variety even though it might create confusion, and dislike having nothing to choose from.

Limitations of Rational Decision Making:

Opponents of rational decision making have pointed out that individuals do not always make rationally maximizing decisions. Therefore, both the processes and results of rational and irrational decision making needs to be studied.

Some of arguments given are as follows:

1. Bounded Rationality - Nobel laureate Herbert Simon proposed the theory of bounded rationality, which says that people are not always able to obtain all the information they would need to make the best possible decision.

2. The problem of collective action - A collective action problem is a situation in which all individuals would be better off cooperating but fail to do so because of conflicting interests between individuals that discourage joint action.

3. The problem of norms and obligation – The social and cultural factor cannot be discarded while making a decision. Many of the decisions are made keeping in mind one's societal norms or any obligation towards friend, family etc. It undermines the rationality of decision making.

4. Many a times people are not thinking rationally and seek acceptance by imitating their peers, rely on intuition on heuristics, or make choices that are heavily influenced by their current emotional state.

5. Learning models - Individuals make choices like those that have worked well for them in the past.

Although there are many irrationalities in rational decision making. It gave thought of representing preferences as a real valued utility function. Decision making then becomes a problem of maximizing utility function. This is the idea behind the expected utility theory. It takes into account the probabilistic nature of situations.

Expected Utility Theory

Expected utility theory is a tool for making decisions facing uncertainty. For a certain act/problem, it considers possible outcomes or utilities.

In its modern form expected utility was first seen in the works of Von Neumann and Morgenstern in their famous book *Theory of Games and Economic Behaviour (1953).* But it had a very humble beginning, which can be traced back to 17th century.

Pascal's Wager

It was from the work of Blaise Pascal that this theory originated. He was a 17th century Mathematician turned Theologist. In his way to prove his point of believing in God. He created a famous theory to prove his point, known as Pascal's Wager.

	God exists	God does not exist
Wager for God	$u_1 = +\infty$	u_2 = finite
Wager against	$u_3 = -\infty$ or finite	u_4 = finite

Let u1, u2, u3, u4 and u5 are 5 utilities. E be the case of God's existence and nE denotes non-existence. The choices are B (believe in God) or nB (not believe in God).

Since u1 is infinite and regardless of the case, u2, u3 and u4 are finite. From these assumptions, expected utility of the two choices can be calculated

$$E(B) = [p * \infty] + [(1-p) * u2] = \infty$$

$$E(nB) = [p * u3] + [(1-p) * u4] = u5$$

Although the numerical values of u3 and u4 are unknown, it is possible to calculate u5 and evidently it if finite. Hence:

$$U5 < \infty \;\; » \;\; E(nB) < E(B)$$

Therefore, Pascal concluded every human being should believe in God.

The opponents of Pascal's wager point out its following fallacies:

1. It does not prove the existence of God, it merely suggests an alternative way of living for an unavoidable death.
2. There are many God's. It does not take into consideration if that possibility is true. In that case what would happen if there are multiple God's.
3. Since, God is omnipotent, he would see through the inauthentic and authentic believer.

Though this theory had flaws, the probabilistic nature of the theory made way for further investigations by numerous other mathematicians in the centuries to come.

St. Petersburg Paradox

Before moving forward, let's understand few concepts important for understanding *St. Petersburg Paradox.*

Bernoulli Trial: The Bernoulli trials are repeated tests of an experiment which works according to the the following rules:

1. Each trial results can be either success or failure;

2. The probability of success is the same for each trial; If the probability of success is denoted by p, the probability of failure i.e. $q=(1-p)$.

Binomial Distribution: Binomial Distribution is simply Bernoulli distribution of *n* random experiments having probability *p*.

$$p(x) = {}^{n}C_{x}\, p^{x}\, q^{n-x},$$

Expected Payoff: It is the weighted average of values that the random variable can take. Simply put, probability of occurrence of each outcome. For example, you flip a fair coin. Every time you get heads, you lose $1, and every time you get tails, you gain $2.

The expected value will be (-1 * 1/2) + (2 * 1/2) = 1/2.

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St. Petersburg Paradox was formulated by Nicolaus Bernoulli in 1713. The problem goes as follows, *Player A will give Franc to player B, if, with an ordinary die, 1 franc if Player B gets 6 in first throw, 2 francs if player B gets 6 in second throw, 3 francs if player B gets 6 in third throw and so on. Players B's expectation is required.* Another part of the problem was the same situation but with payment in geometric progression.

Daniel Bernoulli solved this paradox using expected value associated with probabilities. But, still there were loopholes found by mathematicians like Carl Menger who showed that this game has finite solution only if the utility of winning is bounded.

The paradox has infinite utility which is not possible in real world.

In 1953, John Von-Neuman and Oskar Morgenstern in their book, proposed the theory of expected utility which we see today. Firstly, they defined utility as a numerically measurable quantity. This was based on works of Euclid and Pareto. Neuman & Morgenstern hypnotised that everything can be converted into a measurable number. They also used the much prevailing concept of Diminishing Marginal utility to prove their point.

Let us understand expected utility from an example:

Individual A has a utility function of u(x) = x and Individual B has a utility function of

u(y) = √y.

Two lotteries denoted by L1 and L2 are presented to both individuals. The rules of the lottery L1 are as follows: in order to take part in a lottery, an individual has to pay a fee equal to 300 $ to have a chance to win 525 $ with probability 50% or 325 $ with the remaining probability (also 50%). The rules of the second lottery L2 are as follows: in order to take part in a lottery, an individual has to pay a fee equal to 500 $ to have a chance to win 644 $ with probability 50% or 600 $ with the remaining probability (also 50%). Which of the two lotteries is preferred by each individual?

Calculating the expected utility for both lotteries from the perspective of both individuals.

Expected utilities of individual A for both lotteries are calculated in the following way:

LA1: 0.5 *(525 - 300) + 0.5 * (325 - 300) = 0.5 - 225 + 0.5 * 25 = 125

LA2: 0.5 - (644 - 500) + 0.5 * (600 - 500) = 0.5 - 144 + 0.5 - 100 = 122

While expected utilities of individual B for the same lotteries are:

LB1: 0.5 * sqrt 525 – 300 + 0.5 * sqrt 325 - 300 = 0.5 * sqrt225 + sqrt25 = 0.5*(15+5) = 10

LB2: 0.5 * sqrt 644 – 500 + 0.5 * sqrt 600 - 500 = 0.5 * sqrt144 + sqrt100 = 0.5*(12+10) = 11

Summarising the results in a form of a table. We can clearly see in the

	Lottery L1	Lottery L2
Individual A	LA1= 125	LA2= 122
Individual B	LB1= 10	LB2= 11

Its evident that though the individuals are faced with exactly the same lotteries, they would choose differently based on their expected utilities.

Fallacies in Expected Utility Theory

Although EUT provides a working framework for decision making process, it is not able to explain many irrationalities, paradoxes and fallacies.

Some of them are as follows:

1. Allais Paradox: Maurice Allais proposed a hypothetical situation. The most famous structure goes as follows:

   Subjects are asked to choose between the following 2 gambles, i.e. which one they would like to participate in if they could:

   Gamble A: A 100% chance of receiving $1 million.
   Gamble B: A 10% chance of receiving $5 million, an 89% chance of receiving $1 million, and a 1% chance of receiving nothing.

   After they have made their choice, they are presented with another 2 gambles and asked to choose between them:

   Gamble C: An 11% chance of receiving $1 million, and an 89% chance of receiving nothing.
   Gamble D: A 10% chance of receiving $5 million, and a 90% chance of receiving nothing.

   Explaining the Paradox

   This experiment has been conducted many, many times, and most people invariably prefer A to B, and D to C. So why is this a paradox?

   The expected value of A is $1 million, while the expected value of B is $1.39 million. By preferring A to B, people are presumably maximizing expected utility, not expected value.
   By preferring A to B, we have the following expected utility relationship:

   u(1) > 0.1 * u(5) + 0.89 * u(1) + 0.01 * u(0), i.e.

   0.11 * u(1) > 0.1 * u(5) + 0.01 * u(0)

   Adding 0.89 * u(0) to each side, we get:

   0.11 * u(1) + 0.89 * u(0) > 0.1 * u(5) + 0.90 * u(0),

implying that an expected utility maximiser must prefer C to D. Of course, the expected value of C is $110,000, while the expected value of D is $500,000, so if people were maximizing expected value, they should in fact prefer D to C. However, their choice in the first stage is inconsistent with their choice in the second stage, and herein lies the paradox.

2. Regret Theory: It proposes that while making decisions, individuals anticipate regret and consider it in decision making depending on their choice to reduce or eliminate regret.

3. Loss Aversion: It refers to people's tendency to avoid a loss more than to pursue a similar gain. If people were rational then the feelings invoked by losing something or gaining something (of equal value) ought to be the same. We should feel as pleased that our friend has just given us $100, as we feel bad that we have lost $100.

4. Ellsberg Paradox: Daniel Ellsburg in 1961 purposed a hypothetical experiment which is considered worse than the Allais Paradox violation.

   Subjects are presented with 2 urns. Urn I contain 100 red and black balls, but in an unknown ratio. Urn II has exactly 50 red and 50 black balls. Subjects must choose an urn to draw from and bet on the color that will be drawn - they will receive a $100 payoff if that color is drawn, and $0 if the other color is drawn. Subjects must decide which they would rather bet on:

   A red draw from Urn I, or a black draw from Urn I
   A red draw from Urn II, or a black draw from Urn II
   A red draw from Urn I, or a red draw from Urn II
   A black draw from Urn I, or a black draw from Urn II
   Explaining the Paradox

   One would expect subjects to be indifferent in the first two cases, and they are. However, people uniformly prefer a draw from Urn I in cases 3 and 4. It is impossible to infer judgements about probabilities from these choices - do people regard a draw of a particular color from Urn I as more likely? Certainly not, because otherwise they would not choose Urn I in both cases 3 and 4.

   Why is this? Well, if they choose Urn I in case 3, this implies that they believe (rightly or wrongly) that Urn II has more black balls than red. However, if that is their belief, then they ought to choose Urn II in case 4 - but they don't.
   The primary conclusion one draws from this experiment is that people always prefer definite information to indefinite - Urn II may have more black balls than red, but it may also have more red balls than black.

5. Order Effect: The order in which information is provided has effect on individual decision making.

6. Certainty Effect: Within decision making, the certainty effect is used to describe the impact of certainty on the decision maker. People are drawn to certainty, giving higher preference to options that have high levels of certainty. An option with high certainty (close to 0% or 100%) is more appealing to people than a complex or ambiguous probability. This causes many decision makers to choose options that go against the expected utility of the problem. A reduction in probability has a greater impact on the decision maker if the initial outcome is certain. For example, a reduction in survivability from 100% to 90% would have a greater impact than a reduction in survivability from 70% to 60%

7. Conjunction Fallacy: The *conjunction fallacy* explores how individuals commonly violate a basic probability rule by estimating probability of conjunction of two statements to be more probable than the probability they assign to at least one of its constituent statements.

8. Disjunction Fallacy: The *disjunction fallacy* shows that people estimate a disjunctive statement to be less probable than at least one of its component statements.

There are many more other irrationalities which cannot explained by Expected Utility Theory.

Although expected utility theory is not able to explain many decision-making criteria's, it certainly provides a better way for maximising the expected payoff. By assigning weights and their probabilities the empirical evidence to support our decision increases. The use of expected utility is not restricted to economics but varying areas like education, marriage, child-bearing, migration, crime and so on.

An improvement over Expected Utility Theory is Prospect Theory firstly given by Tversky and Kahneman in 1979, which later resulted in Noble Prize for them. It is discussed in the next section.

Prospect Theory

Prospect theory assumes that losses and gains are valued differently, and thus individuals make decisions based on perceived gains instead of perceived losses. Because of which it is also called loss-aversion theory.

Tversky and Kahneman's most important theoretical contribution is based on 3 important assumptions:

1. The choices are evaluated relative to a reference point, e.g., the status quo.
2. People are risk-averse about gains (relative to the reference point) but risk-seeking about losses.
3. The third premise is loss-aversion: losing *x* hurts more than gaining *x* helps.

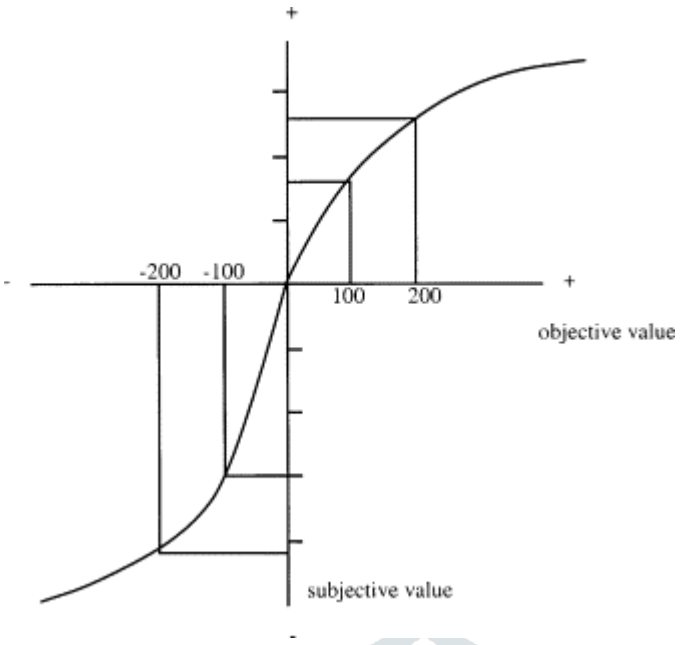
Prospect theory tries to solve the problem in two distinct phases:

(1) Editing phase – The editing phase refers to the way in which individuals characterize options for choice. Most frequently, these are referred to as *framing effects*.

(2) Evaluation phase – This phase involves two component elements. The first element is graphically represented by the value function and second by the weighting function.

Prospect theory replaces the utility function $u(\cdot)$ over states of wealth with a value function $v(\cdot)$ over gains and losses relative to a reference point, with $v(0)=0$.

According to prospect theory, the value function $v(\cdot)$ exhibits the psychophysics of diminishing sensitivity. That is, the marginal impact of a change in value diminishes with the distance from a relevant reference point. The value function is S-shaped; concave in the region of gains above the reference point, convex in the region of losses. Thus, each unit increase in gain (loss) has decreasing value as gain (loss) increases. In other words, the subjective difference between gaining nothing and gaining $100 is greater than the difference between gaining $100 and gaining $200. Finally, the value function is steeper for losses than for gains. This implies that losing $100 is more unpleasant than gaining $100 is pleasant.



Quantum Decision Making

There are many approaches of decision making as discussed above. Expected Utility, Game theory, multi-criteria decision making, etc. It all seems a good way of making decisions until 1980's. A series of experiments performed by Tversky and Kahneman demonstrated that these approaches cannot correctly take into account the uncertainty, ambiguity and risk people face during decision making. Two characteristics of that program were, first, compelling empirical demonstrations that in some decision-making situations naïve observers violate the rules of classic probability (CP) theory and, second, that corresponding behaviour can be explained with simple heuristics.

An attempt for finding a unified theory of decision making that take into account irrationalities, paradoxes, ambiguity and uncertainty has been found. It applies the mathematics of quantum theory of Physics to the field of Decision Making.

The quantum probability research program somewhat originated as an attempt to harmonize the violations of classical probability and express formally some of the key heuristics in decision making.

- Commutative Property: Change in order does not affect the result i.e a+b = b+a but $a - b \neq b - a$
- Associative Property: The grouping of the variables does not affect the result. Exp.- a * (b * c) = b * (a * c)
- Distributive Property: This property combines both commutative and associative property. Exp. – a * (b + c) = a * b * c

Classical Probability theory works by defining a sample space and expressing probabilities in terms of subsets of this space. A key property of this approach is the commutative nature of events and subsequent order independence for probabilities assigned to the joint events. QP is a geometric approach to probability. Events correspond to different subspaces and probabilities are computed by projections to these subspaces. This makes probability assessment potentially order and context dependent and, e.g. – conjunction can fail commutativity. This and related interference effects lead to interesting predictions from QP theory.

To provide a more unified and general theory of decision making, Quantum like models of decision making has been proposed. It can better describe the uncertainty, ambiguity, risks and emotions involved while making a decision and explain the violations and paradoxes and irrationalities in human decision making.

In recent years, one can see a growing interest leading to researches in the application of QDM in the areas psychology, economics, finance, cryptography etc.

An experiment of Tversky and Shafir (1992)

A participant is offered to play a gamble (by tossing a coin) with a 50% chance of winning $200 and a 50% chance of losing $100. After the first play, the participant is offered to play the second identical game with or without the knowledge of the outcome of the first gamble. It has been observed that a majority of participants are ready to accept the second gamble after knowing that they have won the first one, and a majority of participants are also ready to accept the second gamble after knowing that they have lost the first one, but only a small fraction of participants are ready to accept the second gamble if they do not know the outcome of the first gamble.

The experiments performed by Tversky and Shafir (1992) reveal the following:

$$p(A \mid X_1) = 0.69,\ \ p(B \mid X_1) = 1 - p(A \mid X_1) = 0.31$$

$$p(A \mid X_2) = 0.59,\ \ p(B \mid X_2) = 1 - p(A \mid X_2) = 0.41$$

$$p(A) = 0.36 \text{ and } p(B) = 1.p(A) = 0.64$$

It shows that 69% of participants are ready to accept the second gamble if they know that they have won the first gamble, and 59% of participants are ready to accept the second gamble, even if they know that they have lost the first gamble. However, when they do not know the result of the first gamble, only 36% of the participants are ready to accept the second gamble.

We can see that participants prefer to accept the second gamble in either case of win or lose, but when there is uncertainty then a smaller number of participants are willing to accept the second gamble. This is known as disjunction effect. This contradicts sure-thing principle by Savage (1954) and Expected Utility theory.

The Quantum-Like Modelling Approaches to Decision Making tries to explain these kinds of contradictions while making decisions. It cannot be explained by Classical Theories.

Some of the well-developed QDM models in Decision Making are as follows:

- Yukalov and Sornette's Model
- Busyemeyer et al. Model
- Khrennikov's Model
- Agrawal and Shards'a Models

Example of application of Quantum Decision Making

Consider a CEO of a manufacturing company. Strategically, he thinks that he needs to change the positioning of the company, to being more technologically advanced. Doing so will both increase the efficiency of production and convey the right image of the organization to customers and shareholders that is needed to succeed in the future. The board needs to decide in favour of this change in strategic direction, but, historically, investment in new technology has not been a priority for this company and so the probability of them deciding to pursue it is low.

Are there any conditions under which the board might decide to support the CEO's favoured strategy?

Consider an alternative approach the CEO could adopt. He suggests that strategically the organization needs to re-position itself as a more environmentally friendly firm, at the forefront of ensuring high environmental standards, which are increasingly favoured by customers and subject to government guidelines and regulations. This argument might be easier to make, as it resonates with the importance of maintaining a revenue stream. Having made this argument and convinced the board, it might then become easier to persuade them to invest

in new technology to improve efficiency, thereby making their production processes more environmentally friendly.

Depending on the information presented and, critically, the *sequence in which it is presented*, the probability of the board selecting the CEO's preferred approach may be increased, in a way analogous to how the *conjunction fallacy* emerges. In other words, this is a case whereby the probability of a single change (being technologically advanced) is lower than the probability of a (quantum) conjunction (being environmentally friendly and then being technologically advanced. The quantum model predictions regarding the emergence of the conjunction fallacy are order-dependent, in relation to the consideration of the premises. Having accepted the change in relation to being environmentally friendly, it becomes more plausible to accept the further change of being technologically advanced – the first change has a *facilitatory effect* on the second one, because the two share a causal connection. For this to be the case, the two changes must be 'incompatible' (in the quantum sense) and, moreover, one change (which we can call the facilitatory change) must make the target change one more plausible. Finally, clearly, facilitation can occur only if the changes are carried out in a certain order, from facilitatory to target.

Conclusion

The utility function was a revolutionary approach in decision making. Making decisions based on sure numbers is what everyone looks forward to. Although the probabilistic nature, paradoxes, irrationalities, etc. made it hard to comprehend and give a certain result. The recent developments in the field of quantum decision making which utilises the concept of quantum physics to mathematically represent our choices, is showing new hope in decision making. The It is able to explain the fallacies in human decision making such as conjunction and disjunction effect, framing effect and other biases. Of course, these researches are in early stages and a lot of work needs to be done to have it regarded as full-fledged theories.

This report tried to highlight all the theories of human decision making. How it started and where it is headed? It also briefly explained the other techniques which are used to make decisions.

With the rise of artificial intelligence and its application in varied fields like finance, education, healthcare, etc. it is important that more and more precise decisions should be made. The ability to imitate human judgement and improve upon its biases and irrationalities will surpass artificial intelligence over human intelligence.

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