

A Game-Theoretic Framework for Modeling Individual Supportive Dietary Decision-Making

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Abstract

Dietary decision play a crucial role in shaping individual health outcomes; however, such decisions are often made under multiple constraints ,including limited information, personal preferences ,time pressure, and trade-offs between short-term satisfaction and long term health support. From a decision science perspective, dietary behavior can be viewed as strategic decision - making process rather than a simple nutritional choice. This study aims to develop a structured decision - modeling framework that supports individual dietary choices using game theoretic reasoning. This study proposes a game-theoretic framework for modeling individual supportive dietary decision-making by treating the individual as single decision-maker in a non-cooperative single player game .Alternative dietary patterns are modeled as available strategies, while expected health outcomes constitute the associated payoff structure. The proposed framework draws on concepts from operations research and decision analysis, including payoff evaluation, trade-off analysis, and dominance relations, to examine how rational or bounded-rational decisions emerge under realistic constraints. The model further enables the analysis of balance between health support , feasibility ,and behavioral sustainability in dietary choices. This study contributes to the interdisciplinary application of game theory in health-related decision modeling and provides a conceptual foundation for future extensions incorporating uncertainty and multicriteria decision-making approaches , supporting mor systematic and transparent individual dietary decisions

Keywords

Game Theory, Decision Modeling, Operations Research, Dietary Decision-Making, Health Support Systems.

1. Introduction

What we eat is one of the most consequential choices we make every day and its impact on our health and overall quality of life is hard to overstate. yet despite the abundance of nutritional guidelines and health recommendations available today, people rarely choose their food based on health alone . the reality is far more layered .Habits, personal taste , time pressure ,cost , and the social and economic context someone lives in all shape what ends up on their plate (World Health Organization 2020) In practice , most people navigate a constant tension between what they should eat and what they can realistically sustain .A nutritionally optimal diet might look great on paper , but if often demands a level of commitment that simply isn't feasible given the demands of everyday life. On the flip side, mor convenient choices tend to stick precisely because they're easy but they don't always deliver the long term health benefits that matter .Research in heath decision making has consistently shown that this push and pull between health outcomes and real world practicality is what actually drives dietary behavior (Sobal and Bisogni 2009). Operations research and decision analysis offer useful tools for situations exactly like this where multiple options exist , objectives compete, and trade offs are unavoidable . Rather than assuming people make perfectly rational decisions , these approaches provide structured ways to analyze choices under realistic constraints (Clemen and Reilly 2013) that said , while these methods are well established in engineering and management, their application to individual dietary decision making has remained surprisingly limited . Game theory ,in particular , offers a compelling lens for thinking about food choices as a strategic process . under this framework , different dietary patterns function as competing strategies , each carrying its own implications for health support , ease of adherence, and long term sustainability .

unlike prescriptive models that treat optimal behavior as the baseline, game-theoretic approaches can accommodate bounded rationality - the messy , imperfect way people actually make decisions over time (Osborne and Rubinstein 1994) this study proposes a simplified game- theoretic framework for modeling individual dietary decision- making , with focus on the balance between health support , practical feasibility, and behavioral sustainability .In doing so , it aims to bridge game theory , operations research , and health care decision modeling in a way that reflects how food choices are actually made

1.1 Objectives

This study works toward five interconnected goals to address key unique research contributions in dietary decision – making

- To build a simplified game - theoretic framework for modeling individual dietary decisions that reflects realistic behavior rather than idealized assumptions.
- To map different dietary patterns as competing strategies , evaluating their payoffs in terms of health support and practical feasibility.
- To analyze the trade-offs between health benefits, everyday feasibility , and the long -term sustainability of chosen dietary approaches.
- To demonstrate the role of operations research as a structured way of thinking through options that accounts for real constraints and competing priorities.
- To establish a conceptual groundwork for future research that can incorporate uncertainty and complex , multi-criteria decision - making approaches.

2. Literature Review

Individual health decision -making is a multi -dimensional process influenced by cognitive , behavioral , and environmental factors. Despite the availability of evidence - based dietary guidelines, food choices are rarely determined by nutritional science alone; rather, they are shaped by personal preferences , habitual behaviors , and situational conditions (World health Organization 2024) Research on food choice behavior further supports this perspective, emphasizing that dietary decisions evolve through continuous interaction between individual values and daily life contexts(Sobal and Bisogni 2009) describe food choice as a dynamic and ongoing process shaped by personal priorities and social realities .Recent behavioral studies employing cluster analysis have also identified distinct dietary decision -making profiles, such as "Cautious," "Impulsive ," and "Well-Habit," demonstrating that healthy decision rates are strongly associated with reaction time , self regulation , and psychological self- efficacy(Long et al.2025). In addition, gamification- based interventions have recently emerged as promising tools for improving dietary adherence and sustainability awareness , with studies reporting measurable improvements in dietary behavior through game-based engagement strategies(Stivalet al.2026) Form an analytical perspective, Operations Research (OR) provides a robust framework for addressing complex decision environments characterized by competing objectives and uncertainty . Decision analysis methods offer systematic approaches for evaluating expected outcomes and supporting rational decision - making processes(Clemen and Reilly 2013). Within healthcare systems , Multi-Criteria Decision Analysis (MCDM) techniques have been widely applied in areas such as resource allocation, healthcare prioritization , and strategic planning , employing advanced methodologies such as Stepwise Weight Assessment Ratio Analysis (SWARA) to support sustainable and scalable decision implementation (Bakary et al.2024). Although these approaches have demonstrated effectiveness at institutional and policy levels, their application to individual dietary decision-making remains relatively limited , particularly in modeling the interaction between health benefits , behavioral feasibility , and long term adherence. In parallel, Game Theory has increasingly attracted attention as an analytical approach for modeling strategic decision -making under uncertainty. Unlike traditional optimization techniques, game-theoretic models allow the representation of competing priorities and uncertain outcomes within structured decision environments. Recent healthcare applications have utilized game-theoretic frameworks to analyze complex medical and behavioral decisions involving multiple possible outcomes and strategic trade-offs . Nevertheless , the application of Game Theory to supportive dietary decision-making at the individual level remains underexplored in the existing literature . This limitation highlights the need for analytical frameworks capable of representing dietary decision-making as a strategic process occurring under uncertain health condition and competing personal priorities.

3. Research Methodology

This study employs a conceptual analytical methodology to develop a strategic framework for modeling individual dietary decision -making . The approach integrates principles form Operations Research (OR) and Game Theory to

transform qualitative dietary behaviors into a structured selection problem. The framework evaluates dietary alternatives across three primary dimensions: nutritional health support, behavioral feasibility, and long term sustainability. following the decision analysis logic of (Clemen and Reilly 2013), the model prioritizes expected consequences over abstract ideals, focusing on the trade-offs inherent in real - world environments where multiple objectives often conflict (Marsh et al. 2016)

3.1 Game -Theoretic Model Description

The proposed model represents dietary decision as a strategic selections process. while classical game theory often involves multi -agent interactions, this framework adapts the structure to a single decision - maker navigating internal and external constraints (Osborne and Rubinstein1994) The model is defined by three core components:(1) The player: The individual agent making the choice;(2) The strategy set :A finite set of dietary patterns (e.g., strict healthy, Balanced, or convenience oriented); and (3) The payoff Function : A composite utility indicator reflecting health benefits, adherence ease, and sustainability (Reluga 2010).

3.2 Bounded Rationality and Decision Constraints

A critical departure from classical optimization is the adoption of Bounded Rationality. As proposed by Simon(1978); the model assumes that individuals do not seek a mathematically perfect optimum but rather a "satisficing" solution -a choice that is sufficient across all dimensions given the constraints of time, cost, and habit. This behavioral realism is supported by recent findings in dietary decision-making profiles which highlight the role of habitual patterns in long-term outcomes (Longet al.2025;Lenget al.2017). The framework rests on the assumption that individuals are primary autonomous decision - makers who operate under identifiable environmental and biological constraints (Sobal and Bisogni 2009).

3.3 Payoff Matrix Construction

To operationalize the framework, dietary alternatives are structured within a payoff matrix. Each strategy (S_i) is assigned estimated utility values based on a multi-criteria evaluation. This representation facilitates a systematic side-by-side comparison, moving the analysis beyond intuitive selection toward a rigorous examination of trade-offs(Rangel2013). This matrix serves as the analytical core, allowing for the determination of whether a dominant strategy exists or if the "optimal" choice shifts dynamically based on the individuals' subjective weighting of criteria such as prioritizing immediate feasibility over long term health (Variyam 2008)

3.4 Model Assumptions

The proposed framework is grounded in the following foundational assumptions to ensure analytical tractability:

- Autonomous Agency: The individual is the primary and sole decision- maker within the base model.
- Information Availability : Dietary alternatives and their general consequences are identifiable and known to the agent (Leng et al.2017).
- Measurability : Health and behavioral outcomes can be meaningfully approximated through comparable qualitative or quantitative indicators.
- Environmental Context : Decisions occur under real-world constraints -specifically time, cost, and established habits - rather than in a theoretical vacuum (World Health Organization 2024)
- Bounded Rationality : Consistent with the behavioral economics of Simon (1978) the model assumes "satisficing" behavior, where individuals navigate trade-offs based on limited cognitive and environmental resources rather than perfect optimization.

4. Model Illustration and Trade-off Analysis

To demonstrate the framework's practical utility, dietary alternatives can be modeled using the payoff concept borrowed from game theory- where each dietary pattern functions as a strategy an individual might choose when deciding what to eat.

For the purposes of illustration, three dietary strategies are assumed, each reflecting a pattern people commonly encounter in real life:

- A strict health- oriented diet built around natural, nutritionally balanced foods.
- A balanced dietary pattern that blends healthy choices with the occasional convenient or fast -food option.
- A convenience- oriented diet that leans heavily on fast or easy -to- prepare foods.

Each strategy is evaluated against three core criteria that capture the fundamental trade-offs in dietary decision-making:

- Expected Health Benefit : The projected positive impact on physical health and physiological outcomes.
- Ease of Adherence : The level of cognitive and behavioral effort required to follow the dietary pattern.
- Long-term Behavioral Sustainability : The potential for maintaining the dietary strategy consistently over time under real -world constraints .

This choice of criteria isn't arbitrary . The nutrition and health behavior literature consistently shows that healthier diets tend to deliver greater health benefits -but that stricter regimens often fall apart over time because they are simply harder to stick to . balanced approaches , by contrast, tend to strike a more workable middle ground across all three dimensions (Willett et al.,2019 ; Sobal & Bisogni,2009).

To formalize this assessment , we define a utility function (U_i) for each dietary strategy (i) , representing the aggregate value derived from these decision criteria

$$U(i) = \sum_{j=1}^3 w_j \cdot x_{ij}$$

Where x_{ij} denotes the performance score of strategy i on criterion j , and w_j represents the importance weight assigned to each criterion by the decision - maker.

Based on this mathematical framework , the following pay off matrix (Table 1) illustrates the qualitative performance of each dietary strategy against the defined criteria:

Table 1. Illustrative payoff matrix of dietary strategies

Dietary strategy	Health Benefit	Ease of Adherence	Long- term sustainability
Strict health- oriented diet	High	Low	Moderate
Balanced dietary pattern	Moderate- high	High	High
Convenience- oriented diet	Low	Very High	Low

The trade -offs embedded in this table are telling .A strict healthy diet offers the strongest health benefit , but its low adherence makes it difficult to sustain .The convenience-oriented diet sits at the other extreme- easy to follow , but weak on both health outcomes and long-term sustainability . the balanced diet doesn't top any single category , but it holds up reasonably well across all three , which is precisely what makes it the most viable choice for most people navigating real -life constraints. From a game theory and decision analysis stand point , this kind of representation helps explain something that purely prescriptive models often cant : why people don't always choose the "healthiest " option , and how factors like time pressure, cost , and habit legitimately shape what counts as the best available strategy . the framework isn't looking for a theoretically perfect solution - its looking for the most balanced and feasible on given the conditions people actually live in. This is where operations research and game theory earn their place in dietary decision modeling . By laying out the trade- offs systematically ,they offer something more useful than another set of recommendations- a structured way of thinking through the choice itself.

5. Results and Discussion

The framework presented in this study makes one thing clear from the outset: dietary decisions aren't simply a matter of knowing what's healthy. what people actually eat is shaped by a much messier mix of behavioral and practical realities - how hard a diet is to stick to , how much time someone has, and the eating habits they've built up over years. this aligns with what food choice research has long argued: that individual dietary behavior constraints, and environmental pressures , not from nutritional knowledge alone (Sobal&Bisogni,2009) Framing dietary patterns as competing strategies - each with its own payoffs across health, feasibility , and sustainability - shifts the way we think about the problem . Rather than asking "What should someone eat ?" , the framework asks "what trade - offs is someone actually navigating ?" that reframing matters . A balanced dietary pattern, for instance , may not be the nutritional ideal in any strict sense , but the literature suggests it often represents the most practical middle ground - meaningful health benefits without the demands that make stricter approaches collapse over time (Willett et al .,2019). The framework also makes a broader point about where operations research fits in health- related decision - making .

Dietary behavior isn't random, and isn't purely personal- it unfolds within a structured environment full of competing pressures. Analytical tools are well suited to that kind of problem, and their potential here extends beyond individuals. the same logic that helps one person think through their options could inform how policymakers design food environments that make healthier choices more accessible in the first place. that said, the model is deliberately simplified, and that simplicity comes with limits. Future work could push this framework in several directions - building in uncertainty around health outcomes, layering in multi - criteria decision -making techniques, or grounding the payoff values in empirical data rather than illustrative estimates.

6. Conclusion

This study set out to build a simplified analytical framework for making sense of how individuals make dietary decision-drawing on game theory and operations research to do it. what the model shows, at its core, is the food choices aren't driven by health knowledge alone. behavioral and practical realities - how easy a diet is follow, how much time it demands, how well it fits into someone's life -carry just as much weight. Treating dietary patterns as competing strategies reframes the problem in a useful way. Instead of asking what the optimal diet is, the framework asks how individuals actually navigate the tension between health benefits practical feasibility, and long -term sustainability. That shift in framing produces a more honest picture of the trade - offs people face every day. this study also points toward a broader opportunity: operations research and game theoretic thinking have real potential in the analysis of health -related lifestyle decisions - not just as theoretical tools, but as foundation for developing more systematic way to understand and improve the environments in which people make dietary choices. The model is conceptual and deliberately kept simple, which means there's plenty of room to build on it. Future research could introduce uncertainty around health outcomes, apply multi-criteria decision - making methods, or use empirical data to assign payoff values with greater precision. At its heart, this study is a first step - an attempt to bring structured analytical thinking in to a research area has largely operated without it, and one that still has considerable ground left to cover.

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Biography

Rasha D. Kamil is a professional researcher at the Scientific Research Commission in Iraq. she holds a Master of Science (MSc) in Operations Research, earned in 2017. Her academic and professional work focuses on the intersection of mathematical modeling and decision science. Her current research interests include application of

Game Theory and Operations Research techniques to model individual health behaviors and dietary decision -making processes . she is dedicated to developing analytical frameworks that bridge the gap between theoretical nutritional guidelines and realistic behavioral constraints, contributing to the field of health -related decision support systems.

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