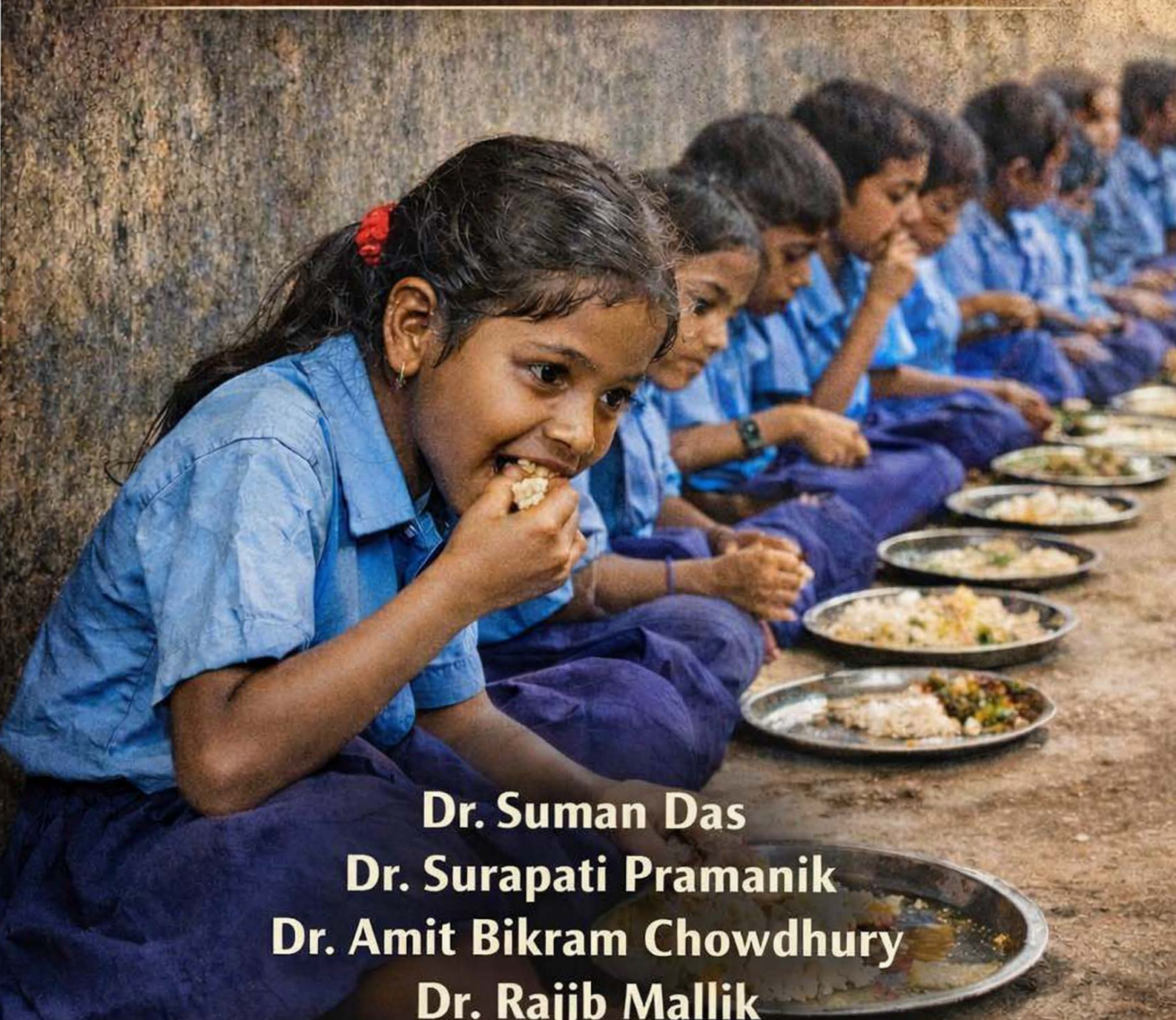
A NEUTROSOPHIC ASSESSMENT OF THE MID-DAY MEAL SCHEME IN INDIA

A Micro-Level Study



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Neutrosophic Science International Association (NSIA)
Publishing House

Gallup - Guayaquil
United States of America – Ecuador
2026

Editor:

Neutrosophic Science International Association (NSIA)
Publishing House
https://fs.unm.edu/NSIA/

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Preface

Public policy evaluation in developing countries is often conducted under conditions of uncertainty, inconsistency, and incomplete information. Large-scale social welfare programs, while designed with clear objectives, operate within complex socio-economic environments where outcomes cannot be classified simply as success or failure. India's Mid-Day Meal Scheme is a prominent example of such a program. Implemented across diverse regions and populations, the scheme simultaneously exhibits measurable achievements, unresolved challenges, and areas of ambiguity.

Most existing studies on the Mid-Day Meal Scheme rely on classical statistical or qualitative approaches that assume determinacy in data and conclusions. Even fuzzy-based models, while allowing partial truth, remain limited in their ability to explicitly represent indeterminacy and contradictory evidence. As a result, important dimensions of uncertainty inherent in policy implementation often remain unaddressed or implicitly ignored.

This book is motivated by the need for an alternative evaluative framework that can realistically capture the coexistence of effectiveness, ineffectiveness, and indeterminacy within a single policy intervention. Neutrosophic logic, with its independent representation of truth, indeterminacy, and falsity, provides a powerful and flexible foundation for such analysis. By adopting a neutrosophic environment, this study moves beyond binary and fuzzy classifications and embraces the complex nature of real-world policy outcomes.

The present work is intentionally designed as a *single, in-depth case study* of India's Mid-Day Meal Scheme. Rather than offering comparative analysis or multiple case investigations, the book focuses exclusively on developing, applying, and interpreting a neutrosophic assessment framework within one nationally significant program. This approach allows for methodological depth, conceptual clarity, and analytical rigor.

The book systematically identifies key attributes of the Mid-Day Meal Scheme such as nutritional adequacy, educational impact, administrative efficiency, food quality, and social equity and evaluates them using neutrosophic parameters. Through structured assessment, aggregation, and sensitivity analysis, the study demonstrates how neutrosophic logic can reveal nuanced insights that are not accessible through conventional evaluation techniques.

This work is intended for researchers, scholars, and policymakers working in the fields of applied mathematics, decision sciences, public policy, education, and social welfare. It also aims to contribute to the growing body of literature on neutrosophic theory by illustrating its practical applicability in social policy analysis.

It is hoped that this book will encourage further exploration of neutrosophic methodologies in evaluating complex social systems and support more informed, uncertainty-aware decision-making in public governance.

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February, 2026

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Chapter 1

Introduction: Education and Society in India

Education in India has long been recognized as a critical instrument for social transformation, economic development, and the promotion of equity. Since independence, the Indian state has viewed education not merely as a means of knowledge transmission, but as a foundational mechanism for nation-building, democratic participation, and social mobility. The expansion of formal schooling has been closely linked to broader development goals, including poverty reduction, improved health outcomes, and the creation of a skilled workforce capable of sustaining economic growth. However, the realization of these objectives remains uneven across regions and social groups.

As a diverse and populous nation, India continues to face persistent challenges related to access, retention, and quality of education. Socio-economic disparities rooted in income, caste, gender, and geography significantly influence educational participation and achievement. Children from marginalized communities often encounter multiple barriers, such as household poverty, child labor, poor health and nutrition, and inadequate school infrastructure. These constraints contribute to irregular attendance, high dropout rates, and low learning outcomes, thereby reinforcing intergenerational cycles of deprivation.

Within this broader educational landscape, school-based welfare interventions have emerged as critical policy instruments for addressing structural inequalities that impede learning. Among these interventions, nutrition programs occupy a central role, as adequate nourishment is closely linked to cognitive development, physical growth, and classroom engagement. For many children from economically vulnerable households, schools serve not only as centers of learning but also as vital points of access to basic welfare services. Integrating education with social protection has therefore become an essential strategy in India's pursuit of inclusive development.

The Mid-Day Meal Scheme represents one of the most ambitious and wide-reaching efforts to combine educational objectives with social welfare provision. By guaranteeing a free, cooked meal to children attending government and government-aided schools, the scheme seeks to enhance enrolment, improve attendance, and reduce classroom hunger. Beyond its immediate nutritional goals, Mid-Day Meal Scheme functions as an incentive for school participation and as a mechanism to alleviate short-term food insecurity at the household level. Its universal nature within public schooling also reflects an attempt to promote social inclusion and reduce visible markers of inequality among children.

Despite its scale and significance, the implementation and outcomes of the Mid-Day Meal Scheme are characterized by considerable variation and uncertainty. Differences in

administrative capacity, local governance, resource availability, and social contexts result in uneven program performance across states and districts. While numerous studies report positive impacts, others highlight concerns related to food quality, hygiene, corruption, and exclusion. These mixed findings underscore the complexity of evaluating large-scale social programs and point to the need for analytical frameworks capable of capturing not only measurable outcomes but also ambiguity, contradiction, and indeterminacy inherent in policy implementation.

1.1 Background of School Nutrition Programs in India

School nutrition programs in India emerged primarily as a response to the persistent problems of child malnutrition, low school attendance, and high dropout rates, particularly among children from economically and socially marginalized communities. Chronic undernutrition has long been recognized as a major impediment to physical growth, cognitive development, and overall learning ability. In a context where a significant proportion of school-age children come from food-insecure households, the absence of adequate nutrition has historically undermined the effectiveness of formal education systems, necessitating targeted welfare interventions within schools.

Prior to independence, initiatives related to school feeding were limited in scope and largely fragmented. Such programs were typically organized at the provincial or municipal level and were often supported by philanthropic organizations, charitable trusts, and missionary institutions. These early efforts, while important in addressing localized needs, lacked uniformity, sustainable funding, and a coherent policy framework. As a result, their reach remained restricted, and they were unable to address the systemic nature of malnutrition and educational exclusion on a national scale.

In the post-independence period, the Indian state began to increasingly acknowledge the close interdependence between nutrition and education as part of its broader development agenda. Policymakers recognized that hunger and undernutrition significantly constrain children's ability to concentrate, attend school regularly, and benefit meaningfully from instruction. This understanding was reinforced by emerging research in health, education, and development economics, which highlighted the long-term consequences of early-life nutritional deprivation on human capital formation and productivity.

Over time, school feeding programs evolved beyond their initial welfare orientation to become multifaceted policy instruments aimed at achieving several interconnected objectives. In addition to improving the nutritional status of children, these programs were designed to enhance enrolment, reduce absenteeism, and discourage early dropout from the schooling system. Moreover, by providing a common meal within schools, nutrition programs were also viewed as mechanisms for promoting social integration, encouraging interaction across caste and class boundaries, and fostering a sense of equality among children in the classroom environment.

Despite their expansion and institutionalization, school nutrition programs in India continue to operate within complex and often challenging conditions. Resource constraints, variations in administrative capacity, and differences in local governance structures contribute to uneven implementation across regions. Socio-cultural factors, including food preferences, caste-based practices, and community perceptions, further influence program effectiveness. These layers of complexity underscore the difficulty of achieving

uniform outcomes and highlight the need for evaluative approaches that can accommodate diversity, uncertainty, and contextual variation in policy performance.

1.2 Genesis and Evolution of the Mid-Day Meal Scheme

The Mid-Day Meal Scheme was formally launched as a centrally sponsored program in 1995, marking a significant shift in India's approach to school education and child welfare. The scheme mandated the provision of cooked meals to children enrolled in government and government-aided primary schools, with the primary objective of enhancing enrolment, attendance, and retention while simultaneously addressing classroom hunger. By institutionalizing school feeding at the national level, the program reflected a growing recognition of the role of nutrition in improving educational participation and learning outcomes.

Although introduced at the central level in the mid-1990s, the origins of the Mid-Day Meal Scheme can be traced to earlier state-level initiatives. Among these, the program implemented in Tamil Nadu stands out as a pioneering model, where school meals were strategically employed as a tool for social welfare and educational inclusion. The success of the Tamil Nadu initiative in increasing school enrolment and attendance, particularly among children from disadvantaged backgrounds, played a crucial role in shaping national policy discourse and provided empirical justification for scaling up the intervention across the country.

Over time, the Mid-Day Meal Scheme underwent substantial expansion in both scope and scale. Initially limited to primary education, the scheme was later extended to cover students at the upper-primary level, thereby widening its reach and potential impact. Nutritional norms were introduced and periodically revised to ensure minimum caloric and protein intake, reflecting evolving understandings of child nutrition and health. The incorporation of food grain allocation through the public distribution system further strengthened the scheme's food security dimension and enhanced coordination across government departments.

Judicial interventions have also played a pivotal role in shaping the evolution of the Mid-Day Meal Scheme. Landmark directives issued by the Supreme Court of India, particularly in the context of the Right to Food case, transformed the scheme from a discretionary welfare measure into a legally enforceable entitlement. These interventions not only accelerated the universalization of Mid-Day Meal Scheme but also emphasized accountability, regularity, and quality in implementation. As a result, the scheme became more firmly embedded within India's rights-based approach to social policy.

Despite these policy advancements, the implementation of the Mid-Day Meal Scheme continues to exhibit considerable regional variation. Differences in administrative capacity, infrastructure availability, financial management, and community involvement contribute to uneven performance across states and districts. Issues related to food quality, hygiene, monitoring, and social inclusion persist in certain contexts, generating mixed and sometimes contradictory outcomes. This variability underscores the complexity of implementing large-scale welfare programs in diverse socio-economic environments and highlights the need for analytical frameworks capable of capturing uncertainty and contextual heterogeneity.

1.3 Rationale for Case Study Selection

Given the vast scale, diversity, and institutional complexity of the Mid-Day Meal Scheme, a case study approach offers a suitable methodological framework for examining how the program operates in specific contexts. National- or state-level aggregate analyses often mask important variations in implementation and outcomes, particularly in a country as heterogeneous as India. A case study enables focused inquiry into localized conditions, allowing researchers to explore how socio-economic, administrative, and cultural factors interact to shape program performance on the ground.

The selected case study represents a setting characterized by pronounced socio-economic diversity, encompassing variations in income levels, social composition, and access to public services. Such diversity provides a meaningful context for examining how the benefits of the Mid-Day Meal Scheme are distributed across different population groups. At the same time, the presence of administrative complexity—manifested through multiple implementing agencies, layers of governance, and varying degrees of institutional capacity—creates conditions in which policy outcomes are neither uniform nor predictable.

A key feature of the chosen case is the observable variability in implementation outcomes across schools and localities. While some institutions demonstrate effective delivery, adequate food quality, and positive educational impacts, others face challenges related to irregular supply, infrastructural inadequacies, or social exclusion. These contrasting experiences coexist within the same administrative setting, producing contradictory evidence regarding program effectiveness. Such variability makes the case particularly suitable for analytical approaches that move beyond binary judgments of success or failure.

The case study context is also well suited for exploring dimensions of uncertainty, indeterminacy, and partial truth—elements that conventional evaluation frameworks often struggle to accommodate. Standard quantitative indicators may capture enrolment figures or nutritional norms but frequently fail to reflect ambiguous or contested realities, such as perceived food quality, informal exclusion practices, or inconsistent monitoring. By situating the analysis within a real-world setting marked by incomplete and sometimes conflicting information, the study creates space for alternative evaluative logics.

Moreover, the case study method facilitates a nuanced understanding of stakeholder perceptions and ground-level realities through the incorporation of qualitative insights. Perspectives of teachers, administrators, cooks, parents, and students provide valuable information about operational challenges, institutional constraints, and lived experiences of the scheme. When combined with quantitative data, these insights enrich the analysis and support a more comprehensive assessment of program performance. This integrative approach strengthens the empirical foundation of the study and aligns with the broader objective of evaluating the Mid-Day Meal Scheme under conditions of uncertainty.

1.4 Problem Statement

Despite widespread recognition of the Mid-Day Meal Scheme as a cornerstone of India's educational welfare policy, assessments of its effectiveness remain fragmented, context-specific, and often inconclusive. While numerous studies have documented positive outcomes in terms of enrolment, attendance, and nutritional intake, others report persistent challenges related to food quality, hygiene, administrative inefficiencies, and social exclusion. These divergent findings reflect not only differences in implementation across regions

but also limitations in the analytical tools traditionally used to evaluate large-scale social programs.

Existing evaluation approaches are predominantly grounded in deterministic or probabilistic models that assume the availability of precise data, stable implementation mechanisms, and clearly identifiable causal relationships between policy interventions and outcomes. Such models often seek to reduce complex social realities to measurable indicators, relying heavily on averages, statistical significance, or binary classifications of success and failure. While useful in controlled or uniform settings, these approaches are ill-suited to contexts characterized by institutional variability, data gaps, and multiple interacting influences.

In practice, the Mid-Day Meal Scheme operates under conditions of ambiguity and partial information. Administrative records may be incomplete or inconsistently maintained, monitoring systems vary in effectiveness, and reported outcomes frequently differ across data sources. Moreover, stakeholder perspectives—including those of students, parents, teachers, cooks, and administrators—often present conflicting narratives regarding program performance. These contradictions are not anomalies but inherent features of a decentralized welfare scheme implemented across diverse socio-economic and cultural environments.

Conventional evaluation frameworks struggle to accommodate such ambiguity and inconsistency, often forcing complex realities into oversimplified categories. As a result, important dimensions of program performance—such as perceived food quality, informal exclusion, irregular delivery, or localized governance challenges—remain underrepresented or entirely excluded from formal assessments. This limitation reduces the explanatory power and policy relevance of evaluation findings, particularly for decision-makers tasked with improving program design and implementation under real-world constraints.

In light of these challenges, there is a clear need for an analytical framework capable of explicitly incorporating uncertainty, inconsistency, and indeterminacy into the assessment of the Mid-Day Meal Scheme. An approach grounded in neutrosophic logic provides a structured means of representing degrees of truth, falsity, and indeterminacy simultaneously, without forcing premature resolution of ambiguity. Such a framework enables a more realistic and nuanced evaluation of Mid-Day Meal Scheme, aligning analytical methods with the complex and uncertain nature of social policy implementation.

1.5 Need for Neutrosophic Assessment

Neutrosophic theory, which extends the foundations of classical and fuzzy logic, provides a comprehensive framework for analyzing systems characterized by complexity, uncertainty, and incomplete information. Unlike binary logic, which restricts evaluation to true or false outcomes, and fuzzy logic, which models degrees of truth alone, neutrosophic logic explicitly incorporates three independent components: truth, falsity, and indeterminacy. This conceptual expansion allows for a more flexible and realistic representation of real-world phenomena, particularly in domains where evidence is partial, inconsistent, or contested.

In the context of the Mid-Day Meal Scheme, several critical dimensions of program performance resist precise measurement. Factors such as nutritional adequacy, impact on attendance and retention, quality of food preparation, administrative efficiency, and beneficiary satisfaction are influenced by multiple interacting variables and are often sub-

ject to divergent assessments. For instance, official nutritional norms may be met on paper, while actual meal quality varies across locations; similarly, attendance figures may improve even as concerns about hygiene or inclusion persist. Such complexities cannot be adequately captured through binary classifications or purely probabilistic models that assume clarity and consistency in underlying data. A neutrosophic assessment enables the simultaneous consideration of positive outcomes, negative evidence, and areas of uncertainty within a unified analytical structure. By assigning degrees of truth, falsity, and indeterminacy to evaluation attributes, the approach accommodates contradictory information without forcing artificial resolution. This is particularly valuable in policy contexts where different data sources, stakeholder perceptions, and monitoring mechanisms produce overlapping yet inconclusive evidence regarding program effectiveness.

Moreover, the neutrosophic framework facilitates the integration of quantitative indicators with qualitative insights, including expert judgments and stakeholder experiences. Rather than treating subjectivity as a methodological weakness, neutrosophic analysis formally incorporates it as a legitimate source of information, while explicitly representing the uncertainty associated with such inputs. This integrative capacity enhances the depth and interpretability of evaluation outcomes, making them more reflective of ground-level realities.

The relevance of neutrosophic assessment is especially pronounced in public policy evaluation within developing country contexts, where data limitations, administrative variability, and socio-cultural diversity are pervasive. In such settings, conventional evaluation methods often struggle to provide actionable insights due to their reliance on idealized assumptions. By acknowledging indeterminacy as an inherent feature of complex social programs, neutrosophic theory offers a pragmatic and context-sensitive approach to policy analysis, thereby strengthening both the analytical rigor and practical utility of the study.

1.6 Objectives of the Study

The objectives of the present study are as follows:

- To examine the implementation and outcomes of the Mid-Day Meal Scheme through a case study approach.
- To identify key factors contributing to uncertainty and indeterminacy in the scheme's performance.
- To develop a neutrosophic framework for assessing school nutrition programs under uncertain conditions.
- To analyze stakeholder perceptions using neutrosophic measures.
- To demonstrate the applicability of neutrosophic theory in educational and social policy evaluation.

1.7 Scope and Delimitations

The scope of the present study is deliberately defined to ensure analytical depth and contextual clarity. The investigation is confined to a selected case study region, allowing

for a focused examination of the Mid-Day Meal Scheme within a specific socio-economic and administrative setting. By adopting a case-based approach, the study prioritizes an in-depth understanding of program functioning over broad generalization, thereby enabling a more nuanced analysis of local implementation dynamics.

The study concentrates exclusively on government and government-aided schools that are formally covered under the Mid-Day Meal Scheme. Private and unaided educational institutions are excluded from the analysis, as they operate under different regulatory and funding frameworks. This delimitation ensures conceptual consistency and allows the evaluation to remain aligned with the policy objectives, operational guidelines, and administrative structures of the Mid-Day Meal Scheme.

Within this defined context, the assessment focuses on key dimensions of program performance, including implementation processes, nutritional adequacy, and selected educational indicators such as student attendance, participation, and regularity of meal provision. Emphasis is placed on operational realities at the school level, encompassing food quality, hygiene practices, administrative coordination, and stakeholder engagement. These dimensions are selected due to their direct relevance to the stated goals of the scheme and their observable variability across implementation settings.

The study does not attempt a nationwide or inter-state comparative analysis, nor does it seek to evaluate long-term health, cognitive, or labor market outcomes extending beyond the school environment. Such outcomes, while important, require longitudinal data and broader analytical frameworks that fall outside the present study's methodological and empirical scope. The focus remains on short- to medium-term outcomes that are directly attributable to the functioning of the Mid-Day Meal Scheme within the selected region.

Several limitations inherent to the research context are acknowledged, including constraints related to data availability, variability in record-keeping practices, and the subjective nature of stakeholder perceptions. Additionally, findings are shaped by the contextual specificity of the case study and may not be directly generalizable to all regions. Rather than treating these limitations as methodological weaknesses, the study addresses them explicitly through the neutrosophic framework, which is designed to incorporate uncertainty, partial information, and indeterminacy into the evaluation process. This approach enhances the transparency and interpretive robustness of the findings.

1.8 Structure of the Book

The book is organized into a sequence of interrelated chapters, each contributing to a systematic examination of the Mid-Day Meal Scheme under a neutrosophic analytical framework. The structure is designed to guide the reader from the broader conceptual and contextual foundations of the study to detailed empirical analysis, followed by interpretation, policy implications, and concluding reflections.

Chapter 1 provides an introduction to the study by situating education and school nutrition within the broader socio-economic context of India. It outlines the background of school nutrition programs, traces the genesis and evolution of the Mid-Day Meal Scheme, and presents the rationale for the selected case study. The chapter also articulates the problem statement, establishes the need for a neutrosophic assessment, defines the objectives of the study, and clarifies its scope and delimitations.

Chapter 2 presents a comprehensive review of existing literature related to India's Mid-

Day Meal Scheme, encompassing studies on nutritional outcomes, educational impacts, administrative and governance issues, and social equity considerations. The chapter critically examines contradictions and inconsistencies in empirical findings and identifies key research gaps that motivate the present study. This chapter also provides the conceptual foundation for adopting alternative evaluation approaches in policy analysis.

Chapter 3 examines the limitations of classical, statistical, and fuzzy evaluation models when applied to complex social welfare programs. By highlighting the inability of these approaches to adequately represent uncertainty and indeterminacy, the chapter establishes the methodological justification for employing neutrosophic logic. This discussion serves as a conceptual bridge between conventional evaluation frameworks and the neutrosophic environment adopted in the study.

Chapter 4 introduces the theoretical foundations of neutrosophic logic, including its origin, core concepts, and formal structures such as neutrosophic sets and numbers. The chapter also discusses the advantages of neutrosophic models over fuzzy and intuitionistic approaches and explores their applicability to public policy analysis. This chapter provides the necessary theoretical grounding for the empirical application that follows.

Chapter 5 outlines the research methodology adopted for the study under a neutrosophic environment. It describes the case study research design, sources of data, role of expert opinion, and procedures for selecting evaluation attributes. The chapter further explains the construction of neutrosophic scales, assignment of truth, indeterminacy, and falsity values, and considerations related to reliability and validity.

Chapter 6 focuses on the identification and conceptualization of neutrosophic attributes relevant to the Mid-Day Meal Scheme. Key dimensions such as nutritional adequacy, enrolment and attendance impact, food quality and hygiene, administrative efficiency, and social equity are examined. The chapter also discusses the interdependence among these attributes and their implications for holistic program evaluation.

Chapter 7 presents the neutrosophic case study analysis of the Mid-Day Meal Scheme. It includes attribute-wise neutrosophic evaluations, construction of neutrosophic vectors, and development of the neutrosophic performance matrix. The chapter pays particular attention to contradictory evidence, zones of high indeterminacy, and their interpretive significance.

Chapter 8 discusses the aggregation of neutrosophic information and sensitivity analysis. It introduces appropriate neutrosophic aggregation operators, derives an overall neutrosophic index for the scheme, and examines the robustness of results under variations in indeterminacy levels. This chapter strengthens the analytical rigor of the study by testing the stability of findings.

Chapter 9 examines the economic dimensions of the Mid-Day Meal Scheme, interpreting the neutrosophic findings through the lens of public finance, household welfare, labor market effects, and human capital formation. The chapter highlights the economic significance of uncertainty in program outcomes and situates the scheme within broader development and welfare economics debates.

Chapter 10 translates the neutrosophic findings into policy-relevant insights. It discusses decision-making under uncertainty, region-specific policy implications, strategies for reducing indeterminacy through improved governance, and the practical utility of neutrosophic assessment for policymakers and administrators.

The final chapter summarizes the key findings of the study and highlights its theoretical, methodological, and policy contributions. It also acknowledges the limitations of the research and outlines directions for future studies, particularly with regard to extend-

ing neutrosophic approaches to other social sector programs and broader comparative contexts.

Chapter 2

Literature Review on India's Mid-Day Meal Scheme

The Mid-Day Meal Scheme has attracted extensive scholarly attention across a wide range of academic disciplines, including education, nutrition, economics, public policy, and sociology. This broad engagement reflects the scheme's multifaceted objectives and its scale as one of the largest school-based welfare interventions in the world. Researchers have approached Mid-Day Meal Scheme not only as an educational initiative but also as a nutrition program, a poverty alleviation mechanism, and a tool for social inclusion, resulting in a rich but diverse body of literature.

A substantial strand of research focuses on the nutritional outcomes of the scheme, examining its role in addressing classroom hunger, improving caloric and protein intake, and contributing to child health. These studies often assess compliance with prescribed nutritional norms and explore variations in meal quality across regions. While several evaluations report positive effects on short-term nutrition indicators, others highlight concerns related to food quality, hygiene, and irregular provision. Such mixed findings point to uneven implementation and the influence of local administrative capacity on nutritional outcomes.

Another important body of literature examines the educational impact of Mid-Day Meal Scheme, particularly its influence on enrolment, attendance, and retention in primary and upper-primary schools. Many studies suggest that the provision of free meals acts as a strong incentive for school participation, especially among children from economically disadvantaged households. However, the magnitude and sustainability of these effects vary across regions and socio-economic contexts, with some research indicating limited or indirect impacts on learning outcomes. These variations underscore the difficulty of isolating causal effects in complex educational environments.

Administrative and governance-related studies form a further strand of the literature, focusing on program design, implementation mechanisms, and institutional accountability. Researchers have analyzed issues such as supply chain management, monitoring systems, financial flows, and the role of local institutions in program delivery. While some studies emphasize improvements in administrative coordination over time, others document persistent challenges, including leakages, capacity constraints, and inconsistent oversight. These governance-related factors significantly shape program performance but are often underrepresented in outcome-focused evaluations.

A growing body of literature also explores the social equity and inclusion dimensions of the Mid-Day Meal Scheme. Scholars have examined how Mid-Day Meal Scheme affects

caste relations, gender participation, and social interactions within schools. Although the scheme is frequently praised for promoting inclusiveness through universal provision, empirical findings reveal instances of discrimination, exclusion, and differential access in certain contexts. Across these diverse strands, findings often diverge due to differences in methodological approaches, data quality, and contextual settings. This fragmentation highlights critical gaps in existing research and underscores the need for integrative evaluation frameworks capable of accommodating uncertainty, contradiction, and contextual variability—gaps that the present study seeks to address.

2.1 Studies on Nutritional Outcomes

A substantial body of research has examined the nutritional impact of the Mid-Day Meal Scheme on school-going children, making nutrition one of the most extensively studied dimensions of the program. These studies generally focus on the scheme's ability to address classroom hunger, enhance daily caloric intake, and improve access to essential nutrients among children from economically vulnerable households. Given the prevalence of undernutrition in many regions of India, Mid-Day Meal Scheme has been widely regarded as a critical intervention for supplementing children's diets during the school day.

Several empirical studies report positive short-term nutritional outcomes associated with participation in the Mid-Day Meal Scheme. Evidence suggests that beneficiaries experience increases in calorie and protein consumption, along with improved intake of selected micronutrients such as iron and vitamins, depending on menu composition. For many children from food-insecure households, the school meal constitutes a significant share of daily nutrition, thereby reducing short-term hunger and improving physical readiness to participate in classroom activities.

Beyond individual dietary intake, the scheme is also viewed as contributing to household-level nutritional security. By providing a free cooked meal at school, Mid-Day Meal Scheme reduces the burden on household food expenditure and enables families to reallocate limited resources toward other consumption needs. This implicit income transfer effect is particularly relevant for low-income households with multiple school-going children, reinforcing the scheme's role as both a nutritional and welfare intervention.

Despite these reported benefits, empirical evidence regarding the scheme's impact on long-term nutritional outcomes remains inconclusive. Indicators such as stunting, wasting, and overall child health are influenced by a range of factors extending beyond school-based interventions, including early childhood nutrition, sanitation, and healthcare access. Several studies note that while Mid-Day Meal Scheme may contribute positively to short-term dietary intake, its influence on chronic forms of undernutrition is limited, particularly in contexts where baseline nutritional deficits are severe.

Concerns related to meal quality, dietary diversity, and implementation consistency further complicate the assessment of nutritional outcomes. Research highlights issues such as inadequate portion sizes, irregular supply of ingredients, limited inclusion of fruits and vegetables, and variations in food safety and hygiene practices. Significant regional disparities in menu design and cooking arrangements reflect differences in administrative capacity and local governance. These variations result in uneven nutritional benefits and generate mixed and sometimes contradictory findings, underscoring the complexity of evaluating the nutritional effectiveness of the Mid-Day Meal Scheme.

2.2 Educational Impact: Enrolment and Attendance

The educational impact of the Mid-Day Meal Scheme has been widely examined in academic and policy-oriented research, with particular emphasis on indicators such as enrolment, attendance, and student retention. As a demand-side intervention, the provision of free cooked meals is intended to reduce economic barriers to schooling and encourage regular participation among children from disadvantaged households. This focus reflects the broader objective of integrating educational access with social welfare support.

A large number of empirical studies report positive associations between the implementation of the Mid-Day Meal Scheme and increased enrolment at the primary level. The scheme is often credited with drawing first-generation learners into the schooling system, particularly in rural and economically backward regions. Improved daily attendance is another frequently cited outcome, as the assurance of a meal provides both an incentive for children to attend school and a motivation for parents to prioritize schooling over alternative uses of children's time, such as household labor.

Retention and reduction in dropout rates also feature prominently in the literature. By addressing short-term hunger and reducing household food expenditure, Mid-Day Meal Scheme is believed to create conditions that support sustained school participation over time. Several studies suggest that the scheme has been particularly effective in retaining students from marginalized social groups, including scheduled castes, scheduled tribes, and girls, thereby contributing to more inclusive educational participation.

Despite these encouraging findings, the impact of the Mid-Day Meal Scheme on learning outcomes and classroom engagement remains a subject of debate. Some researchers argue that improvements in enrolment and attendance do not necessarily translate into enhanced academic performance. Learning outcomes are shaped by a range of factors beyond nutrition and attendance, including teacher quality, pedagogical practices, curriculum relevance, and classroom infrastructure. As a result, the relationship between Mid-Day Meal Scheme and cognitive or academic achievement is often indirect and difficult to isolate empirically.

Moreover, substantial variations in implementation practices across regions and school types contribute to inconsistent findings in the literature. Differences in teacher involvement in meal supervision, time allocated to instructional activities, and the adequacy of school infrastructure influence how the scheme affects the classroom environment. In some cases, the administrative burden of meal provision is reported to disrupt teaching time, while in others, effective coordination enhances the overall school experience. These contextual differences highlight the complexity of assessing educational impacts and underscore the need for evaluative approaches that can accommodate variability and uncertainty in program outcomes.

2.3 Administrative and Governance Studies

Administrative and governance-related studies constitute a significant strand of the literature on the Mid-Day Meal Scheme, focusing on the institutional arrangements and managerial processes that shape program implementation. This body of research examines the organizational architecture underpinning Mid-Day Meal Scheme, including procurement systems, supply chain management, financial flows, and the roles of multiple government departments. Effective coordination among education, food, health,

and local governance institutions is widely recognized as a prerequisite for the smooth functioning of the scheme.

A prominent theme in the literature is the decentralized nature of Mid-Day Meal Scheme implementation. Many studies highlight the involvement of local governments, school management committees, self-help groups, and community-based organizations in meal preparation and delivery. Decentralization is often viewed as a mechanism for enhancing responsiveness, accountability, and community ownership. Empirical evidence from certain regions suggests that locally managed models can improve meal quality, reduce delays, and strengthen monitoring through greater stakeholder participation.

Monitoring and accountability mechanisms also receive considerable attention in governance focused research. Studies assess the effectiveness of inspection systems, record-keeping practices, grievance redressal mechanisms, and the use of technology for tracking fund flows and meal provision. While some evaluations report improvements in transparency through digitization and social audits, others point to uneven implementation of monitoring systems and limited enforcement of accountability measures, particularly in resource-constrained settings.

Despite institutional reforms and policy guidelines, governance challenges persist across many regions. Commonly reported issues include delays in fund disbursement from higher administrative levels, leakages in procurement and distribution, inadequate kitchen and storage infrastructure, and shortages of trained personnel. Workforce-related challenges, such as low remuneration, informal employment conditions, and limited capacity-building for cooks and helpers, further affect program efficiency and morale.

Several studies emphasize the gap between policy design and ground-level execution, highlighting how formal guidelines often fail to translate into consistent practice. Variations in administrative capacity, political commitment, and local leadership play a decisive role in shaping outcomes. In contexts where governance structures are weak or overstretched, even well-designed policies may produce suboptimal results. These findings underscore the importance of viewing Mid-Day Meal Scheme not only as a welfare intervention but also as an administrative system operating under complex and uneven institutional conditions, thereby reinforcing the need for evaluation frameworks that can capture such variability and uncertainty.

2.4 Social Equity and Inclusion Perspectives

From a social justice perspective, the Mid-Day Meal Scheme is widely regarded as an important instrument for promoting equity and inclusion within India's education system. By providing a universal entitlement to free meals in government and government-aided schools, the scheme seeks to reduce socio-economic barriers to schooling and ensure that children from marginalized communities receive equal access to basic nutrition. Scholars frequently highlight the potential of Mid-Day Meal Scheme to contribute to distributive justice by disproportionately benefiting children from economically and socially disadvantaged backgrounds.

A significant body of literature examines the scheme's role in addressing caste-based inequalities and social exclusion. The practice of shared meals within school premises is often interpreted as a deliberate attempt to challenge entrenched social hierarchies by encouraging children from different caste and class backgrounds to eat together. In this sense, Mid-Day Meal Scheme is viewed not only as a nutritional intervention but also as

a social reform measure aimed at fostering interaction, mutual recognition, and a sense of collective belonging among students.

Gender equity is another important dimension explored in the literature. Several studies suggest that the availability of free meals increases school participation among girls, particularly in regions where gender biases influence household decisions regarding education. By reducing the opportunity cost of sending girls to school and addressing nutritional deficits, the scheme is argued to support greater gender parity in enrolment and attendance. These effects are often more pronounced among families facing acute economic constraints.

Despite these positive narratives, empirical studies also document instances of exclusion, stigma, and discrimination in the implementation of the Mid-Day Meal Scheme. In certain contexts, caste hierarchies and social norms influence decisions related to food preparation, serving practices, and participation. Reports of discrimination against children from marginalized communities, as well as resistance to meals cooked by individuals from particular social groups, reveal how deeply embedded social structures can shape program outcomes in ways that undermine egalitarian objectives.

These contrasting findings underscore the socially embedded nature of policy implementation and highlight the limits of universal design in addressing deeply rooted inequalities. While the Mid-Day Meal Scheme possesses significant potential as a tool for social inclusion, its outcomes are mediated by local power relations, cultural norms, and community attitudes. This duality—where inclusionary intent coexists with exclusionary practices—illustrates the complexity of evaluating social welfare programs and reinforces the need for analytical frameworks capable of capturing ambiguity, contradiction, and context-specific variation.

2.5 Contradictions and Data Inconsistencies

A recurring theme in the literature on the Mid-Day Meal Scheme is the presence of contradictory findings and persistent data inconsistencies across empirical studies. While a number of evaluations report significant positive impacts on enrolment, attendance, and nutritional intake, others find only modest or statistically insignificant effects. In some cases, studies even arrive at opposing conclusions when examining similar outcomes, highlighting the absence of a unified empirical narrative regarding the scheme's overall effectiveness.

One major source of inconsistency lies in the diversity of data sources employed across studies. Researchers draw upon administrative records, household surveys, school-level reports, and independent field studies, each of which varies in reliability, coverage, and accuracy. Administrative data may overstate compliance due to reporting incentives, while survey-based data are susceptible to recall bias and sampling limitations. These discrepancies complicate cross-study comparisons and weaken the generalizability of findings.

Methodological variation further contributes to contradictory results in the literature. Differences in evaluation techniques—including cross-sectional analyses, quasi-experimental designs, and longitudinal studies—produce outcomes that are not directly comparable. Variations in time frames, indicators used to measure impact, and assumptions regarding causality also influence results. Studies conducted shortly after implementation may capture short-term effects, whereas longer-term evaluations may reflect

adaptation, dilution of impact, or the influence of external factors.

Geographic and contextual diversity across study settings introduces another layer of complexity. The performance of the Mid-Day Meal Scheme varies significantly across states, districts, and even individual schools, depending on administrative capacity, socio-economic conditions, and local governance structures. Consequently, findings derived from one region may not hold in another, yet are sometimes generalized without sufficient contextual qualification. This spatial heterogeneity amplifies apparent contradictions in the literature.

Collectively, these inconsistencies challenge the applicability of traditional deterministic or purely statistical assessment models, which often assume stable relationships and precise data. When evidence is partial, conflicting, or context-dependent, such models tend to obscure rather than illuminate underlying dynamics. The prevalence of contradictory findings in Mid-Day Meal Scheme research underscores the need for evaluative frameworks that can explicitly accommodate uncertainty, incompleteness, and indeterminacy—limitations that motivate the adoption of alternative analytical approaches in the present study.

2.6 Identified Research Gaps

A critical review of the existing literature on the Mid-Day Meal Scheme reveals several important gaps that limit the comprehensiveness and explanatory power of current evaluations. Despite the extensive volume of research, many studies remain narrowly focused on specific outcomes or employ single-method approaches, resulting in fragmented insights. These limitations constrain the ability of existing scholarship to fully capture the complex and multidimensional nature of the scheme's implementation and impacts.

First, there is a notable lack of integration between quantitative indicators and qualitative stakeholder perceptions, particularly in contexts characterized by uncertainty and variability. While quantitative data provide useful measures of enrolment, attendance, or nutritional norms, they often fail to reflect lived experiences, perceptions of quality, and informal practices that shape program outcomes. Conversely, qualitative studies offer rich contextual insights but are seldom systematically combined with numerical indicators within a unified analytical framework. This methodological separation limits the depth and interpretability of evaluation findings.

Second, most existing studies implicitly assume the availability of precise data and relatively stable implementation environments. Such assumptions overlook the ambiguity, inconsistency, and fluidity that characterize large-scale social welfare programs operating across diverse socio-economic and administrative settings. In the case of the Mid-Day Meal Scheme, variations in governance capacity, record-keeping practices, and stakeholder behavior introduce significant indeterminacy that conventional evaluation models are ill-equipped to address.

Third, there is a conspicuous absence of analytical frameworks capable of systematically handling conflicting evidence and incomplete information. When studies produce divergent or contradictory findings, these inconsistencies are often treated as methodological noise rather than as meaningful features of the policy environment. Traditional deterministic and probabilistic models typically force complex realities into binary or average-based conclusions, thereby obscuring important dimensions of uncertainty and partial truth.

These identified gaps point to the need for alternative evaluation approaches that explicitly recognize and incorporate uncertainty as an inherent characteristic of social policy implementation. The present study responds to this need by applying a neutrosophic assessment framework to the analysis of the Mid-Day Meal Scheme. By modeling degrees of truth, falsity, and indeterminacy simultaneously, the study offers a structured and transparent means of evaluating program performance under conditions of uncertainty, inconsistency, and partial information, thereby contributing both methodologically and substantively to the existing body of knowledge.

Chapter 3

Limitations of Classical and Fuzzy Evaluation Models

The evaluation of large-scale social welfare programs such as India's Mid-Day Meal Scheme necessitates analytical frameworks that can adequately address complexity, uncertainty, and human subjectivity. Programs operating at a national scale involve multiple stakeholders, layered administrative structures, and diverse socio-economic contexts, all of which contribute to variability in implementation and outcomes. Conventional evaluation approaches often struggle to capture these realities, as they tend to prioritize precision, uniformity, and stable causal relationships.

Traditional evaluation models rooted in classical binary logic classify outcomes in terms of success or failure, compliance or non-compliance. While such models offer clarity and simplicity, they are inherently limited in their ability to represent gradations, ambiguity, and partial achievement. In the context of the Mid-Day Meal Scheme, program performance cannot be meaningfully reduced to binary outcomes, as schools may simultaneously exhibit strengths in certain dimensions, weaknesses in others, and indeterminate results in yet others.

Statistical and probabilistic approaches have also been extensively applied in social policy evaluation, particularly for measuring impact through quantitative indicators. These models typically assume the availability of reliable data, consistent implementation, and well-defined relationships between inputs and outcomes. However, in practice, data related to social welfare programs are often incomplete, inconsistent, or subject to reporting bias. Furthermore, statistical averages may conceal significant variations across regions and institutions, thereby limiting the explanatory depth of such analyses.

Fuzzy logic systems represent an important advancement over classical models by allowing degrees of membership rather than binary classification. Fuzzy approaches have been employed to model vagueness and partial truth in social systems, offering greater flexibility in representing imprecise information. Nevertheless, fuzzy logic primarily focuses on the degree of truth of a proposition and does not explicitly account for indeterminacy arising from contradictory evidence, missing data, or unresolved ambiguity. As a result, uncertainty is often conflated with vagueness, leaving certain aspects of complex policy environments insufficiently represented.

The limitations of classical, statistical, and fuzzy evaluation models underscore the need for an alternative analytical environment capable of accommodating ambiguity, inconsistency, and incomplete knowledge. Neutrosophic logic extends existing frameworks by explicitly incorporating degrees of truth, falsity, and indeterminacy as independent

components of analysis. By acknowledging indeterminacy as an inherent feature rather than an analytical inconvenience, a neutrosophic evaluation environment offers a more realistic and comprehensive approach to assessing complex social welfare programs such as the Mid-Day Meal Scheme.

3.1 Classical Binary Evaluation Approaches

Classical evaluation models are fundamentally grounded in binary logic, wherein outcomes are classified into mutually exclusive categories such as true or false, effective or ineffective, and successful or unsuccessful. In the evaluation of social programs, these approaches typically rely on predefined benchmarks, thresholds, or compliance indicators to determine whether objectives have been achieved. Such models assume clarity in both measurement and interpretation, thereby emphasizing definitive judgments over contextual understanding.

The primary appeal of binary evaluation models lies in their simplicity, transparency, and ease of communication to policymakers and administrators. By reducing complex phenomena to categorical outcomes, these approaches facilitate quick decision-making and standardized reporting. However, this simplification often comes at the cost of analytical depth, particularly when applied to multifaceted social interventions that involve human behavior, institutional variation, and socio-cultural diversity.

Programs such as the Mid-Day Meal Scheme operate within heterogeneous environments characterized by regional disparities, administrative differences, and varying levels of community engagement. In such contexts, program performance rarely conforms neatly to binary classifications. A school may meet nutritional norms but struggle with hygiene, or may demonstrate improved attendance without corresponding gains in learning outcomes. Binary models are unable to represent such partial or mixed outcomes, forcing evaluators to overlook important dimensions of performance.

Moreover, binary evaluation approaches inadequately address subjectivity and contextual variation inherent in social policy implementation. Stakeholder perceptions, informal practices, and local constraints significantly influence program outcomes but cannot be meaningfully reduced to yes-or-no judgments. As a result, classical binary models tend to obscure gradations of success, ignore uncertainty, and oversimplify complex realities, thereby limiting their usefulness for comprehensive policy evaluation and reform.

3.2 Statistical Models and Deterministic Assumptions

Statistical evaluation models represent an extension of classical approaches by incorporating probabilistic reasoning, empirical data analysis, and formal inferential techniques. Such models are widely employed in social policy evaluation to estimate causal impacts, identify correlations among variables, and assess program efficiency through indicators such as cost-effectiveness and outcome differentials. Their methodological rigor and reliance on quantitative evidence make them particularly influential in policy discourse and decision-making.

A central assumption underlying statistical models is the availability of complete, reliable, and accurately measured data. These models typically presuppose consistent data

collection procedures, well-defined variables, and sufficient sample sizes to support inference. In addition, causal estimation techniques often rely on assumptions such as stable implementation conditions, exogeneity of treatment, and uniform behavioral responses among beneficiaries. While these assumptions are necessary for formal modeling, they are rarely fully satisfied in large-scale social welfare programs.

In practice, data related to social policy interventions such as the Mid-Day Meal Scheme are frequently incomplete, noisy, or inconsistently reported across administrative levels. Record-keeping practices vary widely across schools and districts, and data may be affected by reporting incentives, human error, or infrastructural constraints. Missing observations, delayed reporting, and discrepancies between official records and field realities introduce significant uncertainty that statistical models are not designed to explicitly accommodate.

Moreover, deterministic assumptions regarding implementation fidelity and beneficiary behavior limit the explanatory power of statistical evaluations. These models often treat program implementation as uniform and beneficiaries as passive recipients, overlooking adaptive behaviors, local innovations, and informal practices that shape outcomes. As a result, statistically estimated averages may conceal substantial heterogeneity across regions, institutions, and social groups, thereby obscuring important dimensions of program performance.

Finally, statistical outputs—such as coefficients, significance levels, and confidence intervals—tend to present results as precise and definitive, even when underlying data are uncertain or contested. Such representations may mask contextual ambiguities, conflicting interpretations, and unresolved contradictions inherent in field-level evidence. Consequently, while statistical models offer valuable insights, their deterministic orientation and limited capacity to represent indeterminacy constrain their suitability for evaluating complex social welfare programs operating under uncertain and variable conditions.

3.3 Fuzzy Logic in Social Policy Evaluation

Fuzzy logic emerged as a significant advancement over classical binary logic by allowing degrees of membership within the continuous interval [0, 1], rather than restricting evaluation to absolute true or false states. This conceptual shift enables the modeling of partial truth, making fuzzy logic particularly attractive for social policy evaluation, where concepts such as “adequate nutrition,” “regular attendance,” or “administrative efficiency” are inherently imprecise and context-dependent. By incorporating linguistic variables and membership functions, fuzzy models provide a more nuanced representation of social phenomena than binary approaches.

In the context of evaluating programs like the Mid-Day Meal Scheme, fuzzy logic allows evaluators to express performance levels in gradated terms rather than rigid categories. For example, a school’s nutritional provision may be considered partially adequate based on calorie content, menu diversity, or frequency of meals. This flexibility enables fuzzy systems to better reflect the continuum along which social outcomes typically exist, thereby improving descriptive realism and interpretability.

Despite these advantages, fuzzy logic systems exhibit important conceptual and methodological limitations when applied to complex social environments. Most fuzzy models rely on a single membership function to aggregate uncertainty into one scalar degree of truth. This aggregation implicitly assumes that all forms of uncertainty can be represented

through gradation alone, thereby reducing complex informational states into a single dimension. As a result, the model is unable to differentiate among distinct sources of uncertainty.

In particular, fuzzy logic conflates vagueness with indeterminacy. Vagueness arises when a concept has blurred boundaries, whereas indeterminacy stems from incomplete information, contradictory evidence, or unresolved ambiguity. For instance, conflicting reports about meal quality or hygiene in different schools cannot be adequately represented by a single degree of membership. Fuzzy models treat such contradictions as averaged or smoothed values, thereby obscuring meaningful informational distinctions.

Consequently, while fuzzy logic represents a valuable improvement over classical binary models, it remains limited in its capacity to fully capture the complexity of large-scale social welfare programs. By collapsing partial truth, ignorance, and contradiction into a unified measure, fuzzy systems risk oversimplifying social realities. These limitations underscore the need for more expressive frameworks—such as neutrosophic logic—that explicitly distinguish between truth, falsity, and indeterminacy, and thereby offer a more comprehensive approach to policy evaluation under uncertainty.

3.4 Inability to Represent Indeterminacy

A fundamental limitation shared by both classical and fuzzy evaluation models is their inability to explicitly represent indeterminacy as a distinct analytical construct. Indeterminacy refers to states in which information is incomplete, contradictory, ambiguous, or contextually unstable, such that a definitive assessment cannot be made. In the evaluation of complex social welfare programs, indeterminacy is not an exception but a recurring and structurally embedded feature of the policy environment.

In large-scale interventions such as the Mid-Day Meal Scheme, indeterminacy arises from multiple sources. Discrepancies between official records and field observations, variations in stakeholder perceptions, and inconsistencies across administrative levels frequently produce conflicting evidence. Additionally, dynamic implementation conditions—such as changes in funding, staffing, or local governance—introduce uncertainty that cannot be resolved through additional data alone. These factors generate informational states that are neither clearly true nor clearly false.

Classical binary logic is inherently ill-equipped to address such conditions, as it requires definitive classification into mutually exclusive categories. When confronted with incomplete or conflicting information, binary models either force arbitrary decisions or exclude ambiguous data altogether. This approach results in the loss of valuable contextual information and may produce misleading conclusions about program performance.

Fuzzy logic, while more flexible, also lacks a formal mechanism to isolate indeterminacy. By representing uncertainty solely through degrees of membership, fuzzy systems collapse distinct informational states—such as partial truth, ignorance, and contradiction—into a single scalar value. As a consequence, indeterminacy is inaccurately absorbed into measures of vagueness or probabilistic uncertainty, obscuring its underlying causes and analytical significance.

The absence of an explicit representation of indeterminacy in both classical and fuzzy frameworks leads to oversimplified interpretations of policy outcomes. Uncertainty is either ignored, averaged out, or mischaracterized, thereby limiting the diagnostic and explanatory power of evaluation models. This limitation underscores the need for an

analytical framework that treats indeterminacy as an independent dimension of analysis—an approach that forms the conceptual foundation for neutrosophic evaluation in the present study.

3.5 Need for Neutrosophic Environment

Neutrosophic logic offers a comprehensive and flexible framework for addressing the conceptual and methodological limitations of classical and fuzzy evaluation models. By introducing three independent components—truth (T), falsity (F), and indeterminacy (I)—neutrosophic logic moves beyond binary classification and single-dimension uncertainty representation. This triadic structure acknowledges that real-world phenomena, particularly in social systems, cannot always be evaluated using mutually exclusive or fully resolved judgments.

A defining strength of neutrosophic logic is its capacity to represent situations in which information may be simultaneously partially true, partially false, and partially indeterminate. Unlike fuzzy logic, which aggregates uncertainty into a single degree of membership, neutrosophic logic preserves the independence of these components. This distinction is crucial in policy evaluation contexts where evidence may be incomplete, contradictory, or evolving, and where uncertainty itself carries meaningful analytical value.

In the evaluation of large-scale social welfare programs such as the Mid-Day Meal Scheme, the presence of indeterminacy is unavoidable. Nutritional adequacy, attendance impact, food quality, and administrative efficiency are influenced by multiple interacting factors and assessed using data of varying reliability. A neutrosophic environment allows these dimensions to be evaluated without forcing artificial precision or eliminating ambiguous information. Quantitative indicators can coexist with qualitative judgments and expert opinions within a unified analytical structure.

By explicitly modeling indeterminacy, neutrosophic assessment enhances transparency and interpretability in evaluation outcomes. Rather than concealing uncertainty within averages or probabilistic assumptions, the neutrosophic approach makes uncertainty visible and measurable. This feature enables policymakers and researchers to distinguish between areas of confirmed success, identified failure, and unresolved ambiguity, thereby supporting more informed and context-sensitive decision-making.

Overall, the neutrosophic environment provides a more realistic and robust analytical approach for social policy evaluation under conditions of uncertainty. Its ability to integrate diverse forms of evidence while preserving informational nuance makes it particularly suitable for assessing the Mid-Day Meal Scheme. By accommodating inconsistency, partial truth, and indeterminacy, neutrosophic logic offers a methodological foundation that aligns closely with the complex realities of public policy implementation in developing country contexts.

Chapter 4

Neutrosophic Logic: Concepts and Foundations

Neutrosophic logic provides a generalized mathematical and philosophical framework for addressing uncertainty, inconsistency, and incomplete information in complex systems. Developed as an extension of classical, fuzzy, and intuitionistic logic, neutrosophic logic challenges the assumption that all knowledge can be reduced to precise or probabilistically bounded representations. Instead, it acknowledges the inherently imperfect and evolving nature of information, particularly in real-world decision-making contexts.

A defining feature of neutrosophic logic is its explicit recognition of indeterminacy as an independent and essential component of knowledge representation. Unlike classical logic, which operates strictly within binary truth values, and fuzzy logic, which models uncertainty through degrees of truth alone, neutrosophic logic introduces a triadic structure consisting of truth (T), indeterminacy (I), and falsity (F). These components are treated as mutually independent, allowing a proposition to simultaneously possess varying degrees of truth, falsity, and unresolved ambiguity.

The philosophical foundation of neutrosophic logic lies in its departure from absolutism and its embrace of contextual and contradictory knowledge. In many practical situations, particularly in social sciences, evidence may be incomplete, sources may conflict, and interpretations may vary across stakeholders. Neutrosophic logic provides a formal means of representing such conditions without forcing artificial resolution or simplification, thereby preserving informational richness and analytical transparency.

From a mathematical perspective, neutrosophic logic introduces constructs such as neutrosophic sets, neutrosophic numbers, and neutrosophic relations, which generalize traditional set theory and numerical representations. These constructs enable the modeling of complex phenomena where boundaries are fluid, measurements are uncertain, and evaluative judgments are subjective. By allowing each element to be associated with independent T, I, and F values, neutrosophic models offer enhanced expressive power over existing logical systems.

The relevance of neutrosophic logic extends naturally to complex decision-making environments such as public policy analysis, where uncertainty, inconsistency, and partial information are intrinsic. Policies like the Mid-Day Meal Scheme involve multiple objectives, stakeholders, and contextual variables that resist precise measurement and uniform interpretation. By providing a structured framework to accommodate uncertainty and indeterminacy, neutrosophic logic offers a robust foundation for evaluating and informing policy decisions under real-world conditions.

4.1 Origin of Neutrosophic Logic

Neutrosophic logic was introduced by Florentin Smarandache as a comprehensive extension of classical logic, fuzzy logic, and intuitionistic fuzzy logic. The theory emerged from the recognition that existing logical systems were insufficient for modeling situations involving incomplete, inconsistent, or contradictory information. While classical logic restricts propositions to binary truth values and fuzzy logic permits degrees of truth, both frameworks impose structural constraints that limit their applicability to complex real-world problems.

The development of neutrosophic logic was motivated by the need to represent uncertainty and contradiction as fundamental features of knowledge rather than as anomalies to be resolved. Smarandache's work draws upon philosophical logic, non-classical logic, and generalized set theory to propose a more expressive formal system. By challenging the assumption that truth and falsity must be complementary or bounded, neutrosophic logic opens new avenues for reasoning under uncertainty.

A central philosophical premise of neutrosophic logic is that knowledge is inherently dynamic, context-dependent, and often paradoxical. In many domains—particularly in social sciences, decision-making, and human-centered systems—information evolves over time and may be subject to multiple, conflicting interpretations. Neutrosophic logic accommodates this reality by allowing truth, falsity, and indeterminacy to coexist without imposing artificial constraints on their relationships. Formally, neutrosophic logic posits that every proposition is characterized by three independent degrees: truth (T), indeterminacy (I), and falsity (F). Unlike intuitionistic fuzzy logic, where the sum of truth and falsity is constrained, neutrosophic logic treats these components as mutually independent. This independence enables the representation of paradoxical statements, ambiguous evidence, and incomplete knowledge in a mathematically consistent manner.

Through this triadic and non-restrictive structure, neutrosophic logic provides a more flexible and powerful framework for knowledge representation than existing logical systems. Its ability to model uncertainty, inconsistency, and indeterminacy makes it particularly well suited for analyzing complex systems where definitive conclusions are unattainable. As such, neutrosophic logic has gained increasing relevance in fields ranging from artificial intelligence and decision science to social policy evaluation.

4.2 Truth, Indeterminacy, and Falsity

A fundamental concept in neutrosophic logic is the representation of every proposition through three independent components: truth (T), indeterminacy (I), and falsity (F). These components quantify the degree to which a statement is true, indeterminate, or false, respectively. In standard neutrosophic logic, each component is typically defined within the interval $[0, 1]$, although generalized and extended neutrosophic frameworks permit values outside this range to capture over- or under-determined information.

Unlike classical probability theory or intuitionistic fuzzy logic, neutrosophic logic does not impose a normalization constraint on the sum of T, I, and F. That is,

$$T + I + F \neq 1 \quad \text{necessarily.}$$

This lack of restriction reflects the reality that information about a proposition may be incomplete, excessive, or contradictory. For example, a policy outcome may be supported

by strong evidence while simultaneously being contested by conflicting reports, resulting in non-zero values for both truth and falsity, along with a residual degree of indeterminacy.

The truth component (T) represents the extent to which available evidence supports a given statement or evaluation criterion. In the context of social policy analysis, truth may be derived from quantitative indicators, documented outcomes, or consistent stakeholder observations. However, truth in neutrosophic logic is not absolute; it is understood as a degree that may vary across contexts, sources, and time periods.

The falsity component (F) captures the extent to which evidence contradicts or negates a proposition. This may arise from empirical counterexamples, negative outcomes, or stakeholder dissatisfaction. Importantly, falsity is treated as an independent dimension rather than as the complement of truth. This independence allows neutrosophic logic to represent situations where evidence simultaneously supports and contradicts a given claim, a condition frequently encountered in large-scale social interventions.

The indeterminacy component (I) is the defining feature that distinguishes neutrosophic logic from earlier logical frameworks. Indeterminacy represents uncertainty arising from incomplete data, conflicting information, ambiguity in measurement, or divergence in stakeholder perspectives. In social systems such as the Mid-Day Meal Scheme, indeterminacy may result from inconsistent reporting across administrative levels, subjective judgments regarding quality or effectiveness, or evolving implementation conditions.

By explicitly separating indeterminacy from truth and falsity, neutrosophic logic provides a more granular and transparent representation of knowledge. Rather than forcing uncertain information into probabilistic averages or fuzzy degrees, the neutrosophic framework preserves ambiguity as an analytically meaningful category. This capability enhances the realism and interpretability of evaluations conducted under conditions of uncertainty, making neutrosophic logic particularly suitable for complex social policy assessment.

4.3 Neutrosophic Sets

Neutrosophic sets constitute a fundamental mathematical construct within neutrosophic logic and represent a significant generalization of classical sets, fuzzy sets, and intuitionistic fuzzy sets. While classical set theory restricts membership to binary values and fuzzy set theory allows partial membership through a single degree, neutrosophic sets extend this framework by explicitly incorporating indeterminacy alongside truth and falsity.

Formally, let U be a universe of discourse. A neutrosophic set A in U is defined as:

$$A = \{\langle x, T_A(x), I_A(x), F_A(x)\rangle : x \in U\},$$

where $T_A(x)$, $I_A(x)$, and $F_A(x)$ denote the truth-membership, indeterminacy-membership, and falsity-membership degrees of the element x with respect to the set A. These functions typically take values in the interval $[0, 1]$, although extended neutrosophic sets permit values outside this range to accommodate over-determined or under-determined information.

The truth-membership function $T_A(x)$ represents the extent to which the element x belongs to the set A, based on available evidence or evaluative criteria. The falsity-membership function $F_A(x)$ captures the degree to which the element does not belong to the set, reflecting contradictory or negative information. Unlike classical and fuzzy sets, neutrosophic sets do not require $T_A(x)$ and $F_A(x)$ to be complementary, allowing both to take non-zero values simultaneously.

The indeterminacy-membership function $I_A(x)$ is a distinctive feature of neutrosophic sets and represents uncertainty arising from incomplete information, ambiguity, or conflicting evidence. Indeterminacy may result from measurement limitations, subjective judgment, or variations across data sources. By explicitly modeling this component, neutrosophic sets preserve informational uncertainty rather than suppressing or averaging it.

An important characteristic of neutrosophic sets is the absence of constraints on the sum of the three membership degrees. That is,

$$0 \leq T_A(x) + I_A(x) + F_A(x) \leq 3,$$

in the general case. This flexibility enables the representation of a wide range of informational states, including inconsistency and paradox, which cannot be captured by classical or fuzzy set theories.

In applied contexts such as social policy evaluation, neutrosophic sets offer a powerful tool for modeling complex attributes that are subject to uncertainty and divergent interpretations. For example, indicators related to nutritional adequacy, administrative efficiency, or beneficiary satisfaction may be associated with varying degrees of confirmation, contradiction, and indeterminacy. Neutrosophic sets provide a structured mathematical framework for representing these nuanced evaluative judgments, thereby enhancing the analytical depth and realism of assessment models.

4.4 Neutrosophic Numbers

Neutrosophic numbers extend the concept of neutrosophic sets into a numerical framework, enabling the quantitative representation of uncertainty, inconsistency, and partial information. While neutrosophic sets associate each element with three membership functions, neutrosophic numbers encapsulate these components within a structured numerical form. A neutrosophic number is typically represented as an ordered triplet (T, I, F), where T, I, and F denote the degrees of truth, indeterminacy, and falsity, respectively.

In standard formulations, the components of a neutrosophic number are real values within the interval $[0, 1]$. However, extended neutrosophic systems allow these values to exceed the unit interval to accommodate over-determined or under-determined information. Importantly, there is no constraint requiring the sum $T + I + F$ to equal unity, reflecting the independent and non-exclusive nature of the three components.

Among the commonly used variants, single-valued neutrosophic numbers (SVNNs) are particularly prominent in applied research due to their computational simplicity and interpretability. A single-valued neutrosophic number is defined as (T, I, F) with $T, I, F \in [0, 1]$. Another widely used variant is the interval neutrosophic number (INN), in which each component is represented as an interval rather than a single value. Interval representations are especially useful when expert opinions vary or when precise quantification is not feasible.

Neutrosophic numbers support a wide range of arithmetic operations and aggregation mechanisms, including addition, multiplication, weighted averaging, and distance measures. These operations enable the combination of multiple criteria, expert evaluations, and data sources within a unified analytical framework. By preserving the distinct contributions of truth, indeterminacy, and falsity, neutrosophic aggregation avoids the loss of information that often occurs in classical or fuzzy numerical models.

In decision-making and evaluation contexts, neutrosophic numbers provide a powerful tool for integrating qualitative judgments, expert opinions, and quantitative indicators under uncertain conditions. Their flexibility and expressive capacity make them particularly suitable for multi-criteria decision analysis, risk assessment, and public policy evaluation. In the assessment of complex social programs such as the Mid-Day Meal Scheme, neutrosophic numbers enable evaluators to represent performance attributes in a manner that reflects both empirical evidence and unresolved uncertainty, thereby enhancing the robustness and transparency of the analysis.

4.5 Advantages over Fuzzy and Intuitionistic Models

Fuzzy logic and intuitionistic fuzzy logic represent important developments beyond classical binary reasoning by introducing mechanisms to handle vagueness and partial truth. Fuzzy logic allows elements to belong to a set with varying degrees of membership, while intuitionistic fuzzy logic further incorporates non-membership and a hesitation margin. These frameworks have been widely applied in decision-making and social system analysis due to their ability to model imprecision more effectively than binary approaches.

Despite their usefulness, both fuzzy and intuitionistic fuzzy models impose structural constraints that limit their expressive capacity in complex and uncertain environments. In fuzzy logic, uncertainty is represented solely through a single membership function, which conflates vagueness with other forms of uncertainty such as incomplete information or conflicting evidence. As a result, fuzzy models are unable to distinguish whether a low degree of membership arises from partial truth, lack of information, or contradictory observations.

Intuitionistic fuzzy logic extends fuzzy logic by introducing explicit non-membership and a hesitation degree. However, this framework still enforces a restrictive condition whereby the sum of membership and non-membership degrees must not exceed unity. The hesitation component is thus implicitly determined by the remaining portion, rather than being independently assessed. This constraint limits the model's ability to represent situations where both supporting and opposing evidence are strong or where indeterminacy dominates the evaluation.

Neutrosophic logic overcomes these limitations by allowing truth (T), indeterminacy (I), and falsity (F) to vary independently of one another. There is no requirement for normalization or complementarity among these components, enabling the simultaneous representation of partial truth, partial falsity, and unresolved ambiguity. This flexibility is particularly important in real-world contexts where evidence may be incomplete, inconsistent, or evolving over time.

By explicitly separating indeterminacy from truth and falsity, neutrosophic logic provides a more realistic and transparent representation of knowledge. Contradictory information, uncertain data, and divergent stakeholder perspectives can be modeled without distortion or forced averaging. Consequently, neutrosophic models offer greater analytical flexibility and realism than fuzzy and intuitionistic fuzzy frameworks, making them especially well suited for complex decision-making environments such as public policy evaluation and social welfare program assessment.

4.6 Applicability to Public Policy Analysis

Public policy analysis is inherently complex, involving multiple stakeholders, heterogeneous data sources, and dynamic implementation environments. Large-scale social programs, such as India's Mid-Day Meal Scheme, operate across diverse socio-economic, geographic, and cultural contexts. Variations in administrative capacity, resource allocation, local governance, and community participation create conditions of uncertainty and indeterminacy that are difficult to capture using traditional evaluation models. Moreover, policy outcomes are influenced not only by measurable quantitative indicators but also by qualitative factors such as stakeholder perceptions, informal practices, and social norms.

Traditional evaluation approaches, whether based on classical, statistical, or fuzzy logic, often struggle to adequately represent these complexities. Classical models impose binary classifications, statistical models rely on assumptions of data completeness and stable causal relationships, and fuzzy models conflate vagueness with indeterminacy. As a result, conventional frameworks may obscure conflicting evidence, ignore partial truths, and fail to capture the nuanced realities of program implementation, thereby limiting their usefulness for evidence-based policymaking.

Neutrosophic logic offers a powerful and flexible alternative for public policy evaluation by explicitly modeling uncertainty, inconsistency, and indeterminacy. By representing each proposition in terms of truth (T), indeterminacy (I), and falsity (F), neutrosophic frameworks allow evaluators to quantify not only what is supported or contradicted by evidence but also what remains unresolved or ambiguous. This triadic representation provides a more realistic and transparent account of policy performance than conventional models, enabling evaluators to identify areas of clarity, conflict, and uncertainty simultaneously.

The applicability of neutrosophic logic extends to both quantitative and qualitative dimensions of policy assessment. Empirical data, such as school attendance records or nutritional measurements, can be incorporated alongside expert judgment, stakeholder perceptions, and subjective evaluations. This integration facilitates multi-faceted assessments that respect the complexity of social programs and the diversity of evaluative perspectives. In doing so, neutrosophic models enhance the interpretability and relevance of findings for policymakers, program administrators, and community stakeholders.

In the context of social welfare programs like the Mid-Day Meal Scheme, neutrosophic logic represents a valuable methodological advancement. It not only supports more nuanced and context-sensitive evaluations but also informs decision-making by highlighting areas of indeterminacy and potential improvement. By accommodating uncertainty and partial truth in a structured analytical framework, neutrosophic approaches provide a robust foundation for evidence-based policy formulation, monitoring, and refinement in complex, real-world environments.

Chapter 5

Research Methodology under Neutrosophic Environment

This chapter presents the research methodology adopted for evaluating India's Mid-Day Meal Scheme (MDMS) under conditions of uncertainty, ambiguity, and partial information. The MDMS, as a large-scale social welfare program, operates across diverse socio-economic, cultural, and administrative contexts. Such heterogeneity introduces multiple sources of variability and indeterminacy, including incomplete data, conflicting stakeholder perceptions, and region-specific implementation challenges. Conventional evaluation models—whether statistical, binary, or fuzzy—are limited in their ability to accommodate these complexities, necessitating the adoption of a more flexible and epistemologically richer analytical framework.

To address these challenges, the present study employs a neutrosophic environment grounded in the theory of neutrosophic sets introduced by Smarandache [23]. This framework allows for the explicit, independent representation of truth (T), indeterminacy (I), and falsity (F) as three distinct informational components. For a proposition p evaluated in a neutrosophic environment, we write:

$$\mathcal{N}(p) = (T_p,\ I_p,\ F_p), \quad T_p, I_p, F_p \in [0,1], \quad 0 \leq T_p + I_p + F_p \leq 3.$$

The independence of T, I, and F—unlike the complementarity assumption $P(\text{false}) = 1 - P(\text{true})$ in classical probability, or the constraint $\mu + \nu \leq 1$ in intuitionistic fuzzy sets—is the defining advantage of the neutrosophic approach. It provides a structured mechanism for integrating quantitative performance indicators with qualitative assessments, expert judgments, and stakeholder inputs without forcing artificial reconciliation of conflicting evidence.

The methodology combines both qualitative and quantitative approaches, reflecting the multi-dimensional nature of the MDMS. Quantitative data—including enrolment statistics, attendance records, and nutritional measurements—are complemented by qualitative insights derived from interviews, surveys, and field observations. A case study research design is adopted to facilitate in-depth examination of the selected study region. Figure **??** illustrates the overall research methodology workflow, from data collection through neutrosophic modeling to sensitivity analysis.

The following sections elaborate on: (i) the case study research design, (ii) sources of data, (iii) expert opinion elicitation and subjectivity modeling, (iv) attribute selection, (v) construction of neutrosophic scales, (vi) assignment of (T, I, F) values, and (vii) reliability and validity considerations within the neutrosophic framework.

5.1 Case Study Research Design

The study adopts a case study research design to facilitate a comprehensive and contextualized examination of the Mid-Day Meal Scheme within a specific geographic and institutional setting. Case study methodology is particularly appropriate for evaluating social policies and large-scale welfare programs because it enables the investigation of complex phenomena in their natural environment, where multiple variables interact and outcomes are influenced by socio-economic, administrative, and cultural factors [**?**]. Unlike purely quantitative or cross-sectional approaches, the case study design emphasizes depth, context, and the relationships among system components.

5.1.1 Rationale for Case Study Design

Program outcomes of the MDMS are shaped not only by centrally defined policy guidelines but also by local administrative practices, resource availability, and community engagement. A case study approach enables the systematic exploration of these contextual factors and their impact on program performance. By selecting a representative region, the study captures variations in school infrastructure, governance efficiency, nutritional delivery, and stakeholder participation—variations that aggregate national-level analyses may mask. The design is consistent with the ontological position that social programs are embedded in complex adaptive systems, where causal mechanisms cannot be isolated from context [**?**].

The case study design also directly supports the neutrosophic modeling framework. The neutrosophic approach requires the simultaneous representation of truth, indeterminacy, and falsity for each evaluation attribute. Such triadic assessment is most meaningfully grounded in a detailed, context-rich evidence base—the hallmark of case study research—rather than in thinly distributed national survey data. Specifically, the heterogeneity of school-level data within the case study region provides the empirical variation necessary to discriminate between confirmed performance (T), genuinely uncertain outcomes (I), and confirmed deficiencies (F).

5.1.2 Case Selection and Scope

The case study region is selected using purposive sampling, based on three criteria: (i) administrative representativeness—the region encompasses both urban-fringe and rural schools, reflecting the diversity of MDMS implementation contexts; (ii) data availability—reasonably complete administrative records, attendance data, and prior inspection reports are accessible; and (iii) variation in performance—the region exhibits known heterogeneity in program outcomes, providing meaningful signal variation for neutrosophic analysis.

Within the selected region, a stratified sample of schools is drawn to ensure coverage across school types (government, government-aided), administrative sub-units, and performance levels (high, medium, low, as classified by prior inspections). Table 5.1 summarizes the scope of the case study.

5.1.3 Data Collection Protocol

Within the case study, data collection follows a structured multi-method protocol combining interviews, focus groups, questionnaires, and field observations. Each school visit

Table 5.1: Scope of the case study

Parameter	Details
Geographic unit	Selected district (anonymized for review)
School sample size	45 schools (30 rural, 15 urban-fringe)
School types	Government (34), Government-aided (11)
Administrative blocks	6 blocks
Data collection period	Academic year 2022–23

involves: (a) a structured observation checklist for meal preparation, hygiene, and distribution; (b) a semi-structured interview with the headteacher and one MDMS coordinator; and (c) a student survey administered to a random sample of 10 beneficiaries per school. Focus group discussions are conducted at block level with district nutrition officers and parent-teacher association representatives.

This protocol ensures that ground-level operational realities, subjective experiences, and context-specific variations are captured. The richness of data generated is essential for a neutrosophic analysis in which disagreements and ambiguities among sources are not suppressed but explicitly modeled through the I component.

5.2 Sources of Data

To ensure comprehensiveness, validity, and reliability, the study draws upon multiple sources of data, combining primary and secondary information. This multi-source approach facilitates triangulation, allowing the research to corroborate findings across different types of evidence and reduce potential biases [**?**]. The sources are classified as follows.

5.2.1 Primary Data

Primary data are collected directly from stakeholders involved in the delivery and reception of the MDMS. These include school administrators, teachers, meal providers (cook-cum-helpers), and student beneficiaries. Data collection instruments include:

- **Structured Questionnaires:** Administered to headteachers and MDMS coordinators at each sampled school, covering meal planning, fund utilization, supply chain management, and compliance with nutritional norms. Responses are recorded on a five-point Likert scale that is subsequently mapped to neutrosophic values (see Section 5.5).

- **Semi-Structured Interviews:** Conducted with district-level officials and nutrition specialists to elicit expert judgments on program effectiveness, systemic challenges, and adequacy of resource allocation.

- **Focus Group Discussions:** Held with groups of 6–8 participants (parents, teachers, or community members) per administrative block to capture collective perceptions, local contextual factors, and observed program outcomes.

- **Field Observations:** On-site visits to school kitchens and dining spaces using a standardized observation checklist, assessing hygiene standards, food quality, serving practices, and infrastructure adequacy.

5.2.2 Secondary Data

Secondary data are obtained from:

- Official government reports, Ministry of Education circulars, and National Programme of Mid-Day Meals in Schools (NPMSS) guidelines;
- State-level administrative records covering enrolment, attendance, fund disbursement, and inspection compliance;
- Nutritional benchmarks from the Indian Council of Medical Research (ICMR) and the National Institute of Nutrition (NIN);
- Peer-reviewed literature and prior evaluation studies of the MDMS.

5.2.3 Data Integration and Neutrosophic Representation

The integration of heterogeneous data sources inherently introduces variability and uncertainty. Field observations and stakeholder perceptions may sometimes conflict with official records, while quantitative indicators may not fully capture qualitative dimensions of program performance. For instance, official attendance records may indicate high participation rates, while field observations reveal irregular meal delivery—a contradiction that neither source alone can resolve. These contradictions represent precisely the form of ambiguity for which neutrosophic modeling is designed.

Formally, when two data sources S_1 and S_2 yield assessments $\mathcal{N}_1(p) = (T_1, I_1, F_1)$ and $\mathcal{N}_2(p) = (T_2, I_2, F_2)$ for the same attribute p, their integration is performed using a source-weighted combination:

$$\mathcal{N}(p) = (\lambda_1 T_1 + \lambda_2 T_2,\ \ \lambda_1 I_1 + \lambda_2 I_2,\ \ \lambda_1 F_1 + \lambda_2 F_2)\,, \tag{5.1}$$

where $\lambda_1, \lambda_2 \geq 0$ are source reliability weights satisfying $\lambda_1 + \lambda_2 = 1$, assigned based on the credibility and relevance of each source for the attribute in question. This formulation preserves the contribution of each source's indeterminacy rather than averaging it away.

5.3 Expert Opinion and Subjectivity

Expert opinion constitutes a central component of the neutrosophic assessment framework, particularly in contexts where quantitative data alone are insufficient to capture the complexity of program implementation. Five domain experts—two education administrators, one nutrition specialist, one school inspector, and one policy analyst—are engaged in this study. Their judgments provide context-sensitive evaluations grounded in professional experience and complement empirical data.

5.3.1 Linguistic Variable Modeling

Expert judgments are expressed using linguistic variables (LVs), which are defined as variables whose values are words or sentences in natural language [**?**]. In this study, a five-term LV set is adopted:

$$\mathcal{L} = \{\text{Very Poor (VP)},\ \text{Poor (P)},\ \text{Moderate (M)},\ \text{Good (G)},\ \text{Excellent (E)}\}.$$

Each linguistic term is mapped to a single-valued neutrosophic number (SVNN), $\ell_k \mapsto (T_k, I_k, F_k)$, as defined in Table 5.2. The mapping is constructed so that terms reflecting stronger evidence and expert consensus receive high T and low I values, while terms reflecting ambiguity or mixed evidence receive elevated I values.

Table 5.2: Linguistic variable to SVNN mapping for expert assessments

Linguistic Term	T	I	F
Very Poor (VP)	0.10	0.15	0.90
Poor (P)	0.25	0.20	0.70
Moderate (M)	0.50	0.30	0.45
Good (G)	0.75	0.20	0.20
Excellent (E)	0.90	0.10	0.10

Note that the neutrosophic framework does not impose $T+F = 1$ or $I = 1-T-F$; each component is independently elicited, allowing, for example, a situation where moderate evidence supports both success and failure simultaneously (high I, non-trivial T and F).

5.3.2 Aggregation of Expert Opinions

When multiple experts provide divergent assessments of the same attribute, their individual neutrosophic evaluations are aggregated using the Neutrosophic Weighted Arithmetic Mean (NWAM), with credibility weights ω_e assigned to each expert e based on domain relevance and years of experience:

$$\mathcal{N}_{\text{agg}}(p) = \left(\sum_{e=1}^{E} \omega_e T_e,\ \sum_{e=1}^{E} \omega_e I_e,\ \sum_{e=1}^{E} \omega_e F_e \right), \quad \sum_{e=1}^{E} \omega_e = 1. \tag{5.2}$$

The indeterminacy component of the aggregated assessment is particularly informative: if experts agree (all I_e are low), I_{agg} will be low; if experts diverge significantly (some rate an attribute as Good, others as Poor), the resulting I_{agg} will be elevated, reflecting genuine evaluative uncertainty rather than suppressing the disagreement through averaging.

5.3.3 Inter-Expert Consistency

Expert consistency is assessed prior to aggregation using a neutrosophic adaptation of Kendall's coefficient of concordance W [**?**]. Specifically, for each attribute j, the experts' rank orderings of the truth component T_{ej} are compared across $E = 5$ experts. A value of $W \geq 0.70$ indicates acceptable concordance; attributes falling below this threshold are flagged for additional discussion or assigned elevated I values to reflect unresolved expert disagreement.

5.4 Selection of Evaluation Attributes

The selection of evaluation attributes is a critical methodological step, governed by a systematic process that integrates literature review, policy alignment, expert consultation, and field-level observations. The objective is to identify a parsimonious yet comprehensive set of attributes that captures the multi-dimensional performance of the MDMS while remaining operationally measurable and analytically tractable within the neutrosophic framework.

5.4.1 Attribute Identification Process

The attribute identification process proceeds in four stages:

1. **Literature Review:** A systematic review of peer-reviewed evaluations of school feeding programs and welfare policy assessments yields an initial pool of 22 candidate attributes. These are drawn from studies across India, Brazil, and Sub-Saharan Africa to ensure both local and comparative relevance.

2. **Policy Alignment:** Candidate attributes are mapped against the stated objectives of the NPMSS and Ministry of Education guidelines. Attributes not directly traceable to a program objective or regulatory standard are excluded, reducing the pool to 14.

3. **Expert Consultation:** The five domain experts independently rate the remaining 14 attributes on relevance, measurability, and sensitivity to uncertainty, using a 1–5 Likert scale. Attributes with mean relevance below 3.5 or identified as highly redundant (inter-attribute Pearson correlation > 0.85) are excluded.

4. **Field Validation:** The refined attribute set is piloted in three schools prior to full data collection. Attributes that prove operationally infeasible or generate uniformly indeterminate responses are revised or replaced.

This process yields the final set of seven evaluation attributes presented in Table 5.3, along with their operational definitions and primary data sources.

5.4.2 Attribute Interdependence

Evaluating attributes in isolation may underestimate joint effects. For example, administrative efficiency (Attribute 5) influences nutritional adequacy (Attribute 1) through timely supply chain management, while infrastructure adequacy (Attribute 6) constrains food quality (Attribute 2). These interdependencies are modeled qualitatively through an attribute influence matrix and are taken into account during sensitivity analysis, where coupled perturbations of interdependent attributes are examined (see Chapter 5).

5.5 Construction of Neutrosophic Scales

Neutrosophic scales provide the formal mechanism for converting qualitative judgments, Likert-scale responses, and field observations into (T, I, F) triplets suitable for neutrosophic aggregation. The construction of these scales is attribute-specific, reflecting the distinct measurement characteristics and expected indeterminacy of each attribute.

Table 5.3: Final set of evaluation attributes with operational definitions

No.	Attribute	Operational Definition	Primary Source
1	Nutritional Adequacy	Compliance with ICMR caloric and micronutrient norms per meal	Lab analysis, menu records
2	Food Quality & Hygiene	Observed cleanliness, freshness, and storage standards	Field observation
3	Enrolment & Attendance	Change in enrolment and daily attendance attributable to MDMS	Admin records
4	Social Equity & Inclusion	Participation rates across gender, caste, and income groups	Survey, registers
5	Administrative Efficiency	Timely fund disbursement, compliance with reporting norms	Official records
6	Infrastructure & Resources	Adequacy of kitchen space, utensils, water, and fuel supply	Field observation
7	Community Participation	Involvement of parents, SMC members in monitoring	Interviews, FGDs

5.5.1 Scale Types

Two types of neutrosophic scales are employed:

- **Single-Valued Neutrosophic Number (SVNN) Scales:** Used for attributes with clearly defined, objectively measurable criteria and relatively low inter-rater variability. Nutritional adequacy and attendance impact are assigned SVNN scales, since they are grounded in objective benchmarks (ICMR norms and administrative attendance records).

- **Interval Neutrosophic Number (INN) Scales:** Used for attributes involving significant subjective judgment or expert disagreement. Food quality, social equity, and community participation are assigned INN scales, where each component is expressed as an interval $[\underline{T}, \overline{T}]$, $[\underline{I}, \overline{I}]$, $[\underline{F}, \overline{F}]$ to capture the range of plausible assessments.

5.5.2 Scale Construction Procedure

For each attribute, a five-level linguistic scale is defined corresponding to the linguistic variable set $\mathcal{L}$ in Section 5.3. SVNN and INN values for each linguistic level are determined through the following steps:

1. **Anchor Setting:** The terminal levels (Very Poor and Excellent) are anchored to theoretically extreme neutrosophic values: $(0.10, 0.10, 0.90)$ and $(0.90, 0.10, 0.10)$ respectively, reflecting maximum falsity (minimum truth) and maximum truth (minimum falsity) with minimal indeterminacy.

2. **Intermediate Level Elicitation:** For intermediate levels (Poor, Moderate, Good), the five experts are asked to assign (T, I, F) triplets, and the NWAM (Equation 5.2) is applied to produce consensus SVNN values.

3. **INN Bounds:** For INN scales, the minimum and maximum individual expert assessments at each level define the lower and upper interval bounds, providing a formal representation of inter-expert disagreement.

4. **Monotonicity Check:** The scale is verified to be monotonically ordered in T (increasing from VP to E) and F (decreasing from VP to E), ensuring logical consistency of the scale structure.

Table 5.4 presents the final SVNN scale used for nutritional adequacy (Attribute 1) as a representative example.

Table 5.4: SVNN scale for nutritional adequacy (Attribute 1)

Linguistic Level	T	I	F
Very Poor (VP)	0.10	0.15	0.90
Poor (P)	0.30	0.20	0.65
Moderate (M)	0.55	0.30	0.40
Good (G)	0.75	0.18	0.18
Excellent (E)	0.90	0.10	0.10

5.5.3 Likert-to-Neutrosophic Conversion

For structured questionnaire data collected on a five-point Likert scale, responses are converted to neutrosophic values using the correspondence 1 $\leftrightarrow$ VP, 2 $\leftrightarrow$ P, 3 $\leftrightarrow$ M, 4 $\leftrightarrow$ G, 5 $\leftrightarrow$ E. When a respondent selects rating $r \in \{1, 2, 3, 4, 5\}$, the corresponding SVNN (T_r, I_r, F_r) from Table 5.4 is assigned. For ordinal responses between two levels (e.g., "between Moderate and Good"), linear interpolation is applied:

$$(T, I, F) = (1 - \alpha)(T_\ell, I_\ell, F_\ell) + \alpha(T_{\ell+1}, I_{\ell+1}, F_{\ell+1}), \quad \alpha \in [0, 1], \tag{5.3}$$

where α is the interpolation parameter reflecting the respondent's reported proximity to the higher level.

5.6 Assignment of (T, I, F) Values

The assignment of truth (T), indeterminacy (I), and falsity (F) values is the operational core of the neutrosophic evaluation. This section describes the complete assignment pipeline, from raw data collection through final (T, I, F) triplet derivation for each attribute.

5.6.1 Assignment Pipeline

The assignment process proceeds in five steps, as illustrated schematically in Figure **??**:

1. **Raw Data Collection:** Quantitative indicators (attendance records, nutrient analysis) and qualitative data (expert ratings, field observation scores) are collected for each attribute and school.

2. **Scale Mapping:** Qualitative data are converted to (T, I, F) triplets using the neutrosophic scales from Section 5.5. Quantitative indicators are normalized to the $[0, 1]$ range and mapped to SVNN values using a piecewise linear transformation calibrated to program benchmarks.

3. **School-Level Aggregation:** For each school s and attribute j, assessments from multiple respondents are aggregated using Equation 5.2 with uniform weights ($\omega_e = 1/E$) to produce a school-level neutrosophic assessment $\mathcal{N}_{sj} = (T_{sj}, I_{sj}, F_{sj})$.

4. **Regional Aggregation:** School-level assessments are aggregated across all sampled schools within the case study region using the NWAM with school weights ν_s proportional to school enrolment size:

$$\mathcal{N}_j = \left(\sum_{s=1}^{S} \nu_s T_{sj}, \ \sum_{s=1}^{S} \nu_s I_{sj}, \ \sum_{s=1}^{S} \nu_s F_{sj} \right), \quad \sum_{s=1}^{S} \nu_s = 1. \tag{5.4}$$

5. **Expert Overlay:** The regionally aggregated neutrosophic values are reviewed by the expert panel. Experts may apply upward or downward adjustments to I_j if field conditions suggest systematic reporting gaps not captured in the primary data, using the perturbation mechanism of Equation 8.12 with magnitude $|\delta_j| \leq 0.05$.

5.6.2 Quantitative-to-Neutrosophic Transformation

For a quantitative indicator x_j (e.g., attendance rate, caloric compliance ratio), the piecewise linear transformation to T_j is:

$$T_j(x_j) = \begin{cases} 0 & \text{if } x_j \leq x_j^{\min} \\ \dfrac{x_j - x_j^{\min}}{x_j^{\text{bench}} - x_j^{\min}} \cdot T^{\text{bench}} & \text{if } x_j^{\min} < x_j \leq x_j^{\text{bench}} \\ T^{\text{bench}} + \dfrac{x_j - x_j^{\text{bench}}}{x_j^{\max} - x_j^{\text{bench}}}(1 - T^{\text{bench}}) & \text{if } x_j > x_j^{\text{bench}}, \end{cases} \tag{5.5}$$

where $x_j^{\min}$, x_j^{bench}, and $x_j^{\max}$ are the minimum, benchmark (policy standard), and maximum observed values of the indicator, and T^{bench} is the truth value assigned at benchmark compliance (typically $T^{\text{bench}} = 0.65$, reflecting that meeting the minimum standard is a moderately positive but not fully sufficient outcome). Corresponding transformations for F_j and I_j are defined to be monotonically decreasing and hump-shaped (peaking at intermediate x_j values where outcomes are most ambiguous), respectively.

5.6.3 Illustrative Assignment Example

Table 5.5 presents a worked illustration of the assignment pipeline for nutritional adequacy (Attribute 1) across three representative schools.

The regional aggregate $(0.580, 0.237, 0.342)$ for nutritional adequacy indicates moderate confirmed success (58%), non-trivial indeterminacy (23.7%), and a meaningful level of

Table 5.5: Illustrative (T, I, F) assignment for nutritional adequacy across three schools

School	**Caloric Compliance**	**Expert Rating**	T	I	F	**Source Weight**
School A (urban)	92%	Good	0.78	0.17	0.16	$\nu_A = 0.35$
School B (rural)	74%	Moderate	0.55	0.30	0.38	$\nu_B = 0.40$
School C (rural)	61%	Poor	0.32	0.22	0.61	$\nu_C = 0.25$
Regional Aggregate (Equation 5.4)			**0.580**	**0.237**	**0.342**	

confirmed deficiency (34.2%), driven primarily by the underperformance of rural schools B and C. This nuanced picture—distinguishing between confirmed shortfalls and unresolved uncertainty—would be unavailable under a conventional scalar index.

5.7 Reliability and Validity Considerations

Ensuring reliability and validity in a neutrosophic evaluation framework requires careful methodological planning and rigorous procedures that go beyond conventional psychometric approaches. Because neutrosophic evaluation explicitly incorporates indeterminacy, traditional reliability coefficients (e.g., Cronbach's α, which assume a unidimensional true-score model) require adaptation. This section presents both adapted classical measures and neutrosophic-specific procedures.

5.7.1 Reliability

Internal Consistency

Internal consistency across semantically related attributes is assessed using a neutrosophic generalization of Cronbach's α. Let T_{sj} denote the truth component of the evaluation of school s on attribute j, for $s = 1, \ldots, S$ and $j = 1, \ldots, n$. The T-component reliability coefficient is:

$$\alpha_T = \frac{n}{n-1}\left(1 - \frac{\sum_{j=1}^{n} \sigma^2_{T_j}}{\sigma^2_{T_{\text{sum}}}}\right), \tag{5.6}$$

where $\sigma^2_{T_j}$ is the variance of T_{sj} across schools for attribute j, and $\sigma^2_{T_{\text{sum}}}$ is the variance of the sum $\sum_j T_{sj}$ across schools. Analogous coefficients α_I and α_F are computed for the indeterminacy and falsity components respectively. Acceptable reliability is defined as $\alpha_T, \alpha_F \geq 0.70$ and $\alpha_I \geq 0.60$ (a lower threshold is appropriate for I since inter-school variation in indeterminacy is inherently higher).

Inter-Rater Agreement

For attributes assessed by multiple experts, inter-rater reliability is quantified using the intraclass correlation coefficient (ICC) applied independently to the T, I, and F columns of the expert rating matrix. Specifically, ICC(2,1)—the two-way random effects model for absolute agreement—is computed for each component:

$$\text{ICC}(2,1) = \frac{MS_B - MS_W}{MS_B + (k-1)MS_W + k(MS_A - MS_W)/n}, \tag{5.7}$$

where MS_B, MS_W, and MS_A are the between-targets, within-targets, and between-raters mean squares, k is the number of experts, and n is the number of attributes. An ICC ≥ 0.75 is taken to indicate good agreement. Attributes for which $\mathrm{ICC}(I) < 0.60$ are assigned increased indeterminacy in the final aggregation, reflecting genuine inter-expert uncertainty rather than measurement error.

Test–Retest Stability

A subset of 10 schools (approximately 22% of the sample) is re-evaluated four weeks after the initial data collection round. The neutrosophic distance between the initial and re-evaluated triplets is computed using the generalized Euclidean distance for single-valued neutrosophic numbers [26]:

$$d\big(\mathcal{N}_1, \mathcal{N}_2\big) = \sqrt{\frac{1}{3}\left[(T_1 - T_2)^2 + (I_1 - I_2)^2 + (F_1 - F_2)^2\right]}. \tag{5.8}$$

A mean distance $\bar{d} \leq 0.05$ across all attributes and re-tested schools is taken as evidence of acceptable temporal stability of the assessments.

5.7.2 Validity

Content Validity

Content validity is established through the structured attribute selection process described in Section 5.4, which explicitly links each attribute to MDMS policy objectives and verifies coverage through expert consultation. A Content Validity Index (CVI) is computed for each attribute as the proportion of experts rating it as "relevant" or "highly relevant" (ratings 3 or 4 on a 4-point scale). An attribute-level CVI ≥ 0.78 (the threshold recommended for panels of five or more experts [**?**]) is required for inclusion in the final evaluation.

Construct Validity

Construct validity is assessed by examining the internal structure of the neutrosophic assessment matrix. Specifically, the T-component matrix $(T_{sj})_{S\times n}$ is subjected to exploratory factor analysis (EFA) to verify that the seven attributes cluster into theoretically coherent latent dimensions (e.g., a food-nutrition factor grouping Attributes 1 and 2, an educational impact factor grouping Attribute 3, and a governance factor grouping Attributes 4, 5, and 6). Alignment with the theoretically expected factor structure provides evidence of construct validity.

Criterion Validity

Criterion validity is assessed by correlating the school-level neutrosophic score function $\mathcal{S}(\mathcal{N}_s)$ (computed as the weighted average of attribute-level scores for each school s) with an external criterion: the composite MDMS compliance score assigned by the state government during its annual school inspections. A Spearman rank correlation $\rho_s \geq 0.65$ between the two measures is taken as evidence of adequate criterion validity.

Neutrosophic-Specific Transparency as a Validity Criterion

Beyond conventional validity measures, the neutrosophic framework introduces a uniquely structured form of epistemic transparency as an additional validity criterion. By explicitly decomposing program evidence into confirmed truth (T), confirmed falsity (F), and unresolved indeterminacy (I), the framework makes the epistemic status of each attribution visible and auditable. Attributes or schools with high I values are not assigned unjustifiably high or low summary scores; instead, their uncertainty is formally preserved and reported. This prevents validity-threatening behaviors such as overconfident performance characterization or systematic underestimation of implementation gaps—both common failure modes in conventional scalar evaluation frameworks.

Overall, the reliability and validity procedures presented in this section ensure that the neutrosophic assessment of the MDMS is methodologically rigorous, internally consistent, and externally meaningful. By combining adapted classical psychometric measures with neutrosophic-specific mechanisms for representing uncertainty, the framework achieves both the analytical precision expected in academic evaluation research and the contextual sensitivity required for credible policy analysis.

Chapter 6

Identification of Neutrosophic Attributes for Mid-Day Meal Scheme

The effectiveness of the Mid-Day Meal Scheme is determined by a complex interplay of factors spanning nutritional adequacy, educational outcomes, administrative efficiency, and social inclusion. Each of these dimensions is influenced by a combination of quantitative indicators, qualitative observations, and context-specific variables. For instance, the nutritional impact depends not only on the quantity and quality of meals served but also on local dietary habits, seasonal variations, and supply chain reliability. Similarly, educational outcomes such as enrolment, attendance, and retention are shaped by both policy interventions and broader socio-economic conditions.

These factors are frequently characterized by partial information, subjectivity, and variability across regions, schools, and stakeholder perspectives. Traditional evaluation methods may struggle to capture such nuances, particularly when data are incomplete, contradictory, or ambiguous. In this context, a neutrosophic evaluation framework is particularly valuable because it accommodates degrees of truth (T), indeterminacy (I), and falsity (F) for each attribute, thereby representing not only measurable outcomes but also uncertainty and divergent expert opinions.

Identification of key evaluation attributes is a critical prerequisite for applying neutrosophic analysis. Attributes must be both relevant to the objectives of the Mid-Day Meal Scheme and operationally definable for data collection and assessment. They should encompass the main areas through which program effectiveness is realized, while also being sensitive to variations and indeterminacies inherent in social programs. Careful selection ensures that the resulting neutrosophic assessment reflects a holistic view of the scheme rather than a narrow or incomplete perspective.

This chapter presents the primary neutrosophic attributes selected for evaluating the Mid-Day Meal Scheme. These attributes have been derived from an extensive review of policy documents, academic literature, previous evaluation studies, and field-level observations. Each attribute is operationally defined and linked to specific indicators, while also accommodating subjective judgments and uncertainty through neutrosophic representation. The chapter also discusses the interdependence among attributes, highlighting how interactions between nutritional, educational, administrative, and social factors influence overall program performance.

By systematically identifying and defining these attributes, the study lays the founda-

tion for a rigorous neutrosophic assessment of the Mid-Day Meal Scheme. This approach ensures that both objective data and context-specific uncertainties are integrated into the evaluation, providing a realistic and actionable understanding of program effectiveness under conditions of ambiguity and partial information.

6.1 Nutritional Adequacy

Nutritional adequacy constitutes one of the most fundamental objectives of the Mid-Day Meal Scheme and serves as a critical evaluation attribute. It reflects the extent to which the meals provided in schools meet prescribed dietary standards, including caloric content, protein levels, and essential micronutrients such as iron, calcium, and vitamins. The scheme aims to supplement household nutrition, reduce short-term hunger during school hours, and contribute to the overall health and cognitive development of children. Therefore, assessing nutritional adequacy is central to understanding the effectiveness of the program in achieving its intended outcomes.

While official guidelines provide clear benchmarks for meal composition and portion sizes, actual delivery often varies due to a range of factors. Supply chain limitations, logistical challenges, regional food availability, and local culinary practices can result in deviations from the prescribed nutritional standards. For example, seasonal variations may affect the availability of fresh vegetables, while certain culturally preferred foods may not align perfectly with recommended nutrient profiles. These variations introduce uncertainty into any assessment based solely on nominal policy standards.

Furthermore, evaluating nutritional adequacy involves inherent measurement challenges. Portion sizes may differ across schools, micronutrient content is rarely monitored systematically, and compliance with guidelines can fluctuate on a day-to-day basis. Expert judgments and field observations may also diverge, reflecting differences in perception or access to information. Collectively, these factors generate both ambiguity and variability in the assessment of nutritional outcomes, making traditional binary or purely statistical evaluations insufficient.

The neutrosophic framework is particularly well-suited to address these complexities. By representing nutritional adequacy using degrees of truth (T), indeterminacy (I), and falsity (F), the evaluation can simultaneously capture evidence supporting adequate nutrition, evidence suggesting inadequacy, and uncertainty arising from incomplete or conflicting data. For example, a school may serve meals that generally meet caloric norms (high T), but inconsistencies in micronutrient content or occasional menu deviations may contribute to a moderate indeterminacy (I), while sporadic deficiencies in portion sizes or quality may result in a non-zero falsity (F).

This nuanced representation allows evaluators to incorporate both quantitative data (such as calorie counts, protein measurements, or survey data) and qualitative insights (such as teacher or parent observations) into a single, integrated framework. By explicitly modeling uncertainty and partial information, the neutrosophic assessment of nutritional adequacy provides a more realistic and actionable understanding of program performance, supporting targeted policy interventions and resource allocation decisions.

6.2 Impact on Enrolment and Attendance

The impact of the Mid-Day Meal Scheme on school enrolment and attendance is widely recognized as a key educational outcome, yet empirical documentation of this effect remains uneven across regions and school contexts. Numerous studies indicate that the provision of free meals serves as a tangible incentive for children to attend school regularly, particularly in economically disadvantaged and socially marginalized households. By reducing the opportunity cost of schooling and supplementing household nutrition, Mid-Day Meal Scheme contributes to increased enrolment at the primary level and improved daily attendance rates, aligning with the broader goal of promoting universal education.

Despite these positive trends, attributing changes in enrolment and attendance solely to the Mid-Day Meal Scheme is complex. Educational participation is influenced by a multitude of concurrent factors, including other government programs, local infrastructure, teacher availability, household income, seasonal labor demands, and cultural practices. These overlapping influences introduce ambiguity and complicate causal inference, making it challenging to isolate the specific contribution of the meal program from other determinants of school attendance.

Measurement of enrolment and attendance also presents methodological challenges. Official school records may be incomplete or inconsistently maintained, and self-reported attendance data from households can be subject to recall bias or exaggeration. Regional variability in administrative capacity, record-keeping, and monitoring further contributes to uncertainty in observed outcomes. These factors collectively generate indeterminacy in both the magnitude and direction of the educational impact, which cannot be adequately captured through deterministic or purely statistical models.

The neutrosophic evaluation framework provides a robust solution to these challenges by explicitly modeling truth (T), indeterminacy (I), and falsity (F) for this attribute. Observed increases in enrolment or consistent attendance can be represented with high truth values, while conflicting evidence—such as inconsistencies between official records and field observations—contributes to the indeterminacy component. Negative indicators, such as persistent absenteeism or dropout, are captured in the falsity dimension. This triadic representation allows evaluators to distinguish between verified positive effects, unresolved uncertainty, and potential shortcomings, offering a nuanced and context-sensitive assessment of the educational outcomes associated with Mid-Day Meal Scheme.

By integrating both quantitative metrics and qualitative insights from teachers, administrators, and parents, the neutrosophic approach ensures that the evaluation reflects the complex realities of school participation. This allows policymakers and program managers to identify regions or schools where the scheme is performing effectively, as well as areas where indeterminate or negative trends may warrant targeted intervention, ultimately supporting more evidence-based and adaptive decision-making.

6.3 Food Quality and Hygiene

Food quality and hygiene represent essential attributes of the Mid-Day Meal Scheme, directly influencing both nutritional outcomes and the willingness of children to participate in the program. This attribute encompasses multiple dimensions, including taste, freshness, compliance with safety standards, and hygienic practices in food preparation, storage, and serving. High-quality and safe meals not only ensure that nutritional benefits

are realized but also enhance beneficiary satisfaction and sustained attendance, thereby reinforcing the educational objectives of the scheme.

While there are numerous examples of well-implemented meal programs, concerns regarding food quality and hygiene remain prevalent in many contexts. Instances of contamination, substandard ingredients, inadequate cooking facilities, and insufficient training of kitchen staff have been documented in various evaluations. These challenges are often compounded by infrastructural limitations, irregular inspection regimes, and variations in local administration capacity. Such issues can undermine the effectiveness of the Mid-Day Meal Scheme, negatively affecting both health outcomes and community trust in the program.

Assessing food quality and hygiene presents inherent difficulties. Unlike objective indicators such as caloric content or enrolment numbers, evaluations of taste, freshness, and cleanliness are highly subjective and context-dependent. Stakeholder perceptions—including those of teachers, parents, meal providers, and children—may vary widely, influenced by personal expectations, cultural preferences, and prior experiences. Additionally, systematic measurement of contamination or adherence to hygiene protocols is often limited by resource constraints, further contributing to incomplete information.

Neutrosophic modeling offers a robust framework for capturing these complexities. By assigning independent truth (T), indeterminacy (I), and falsity (F) values, the evaluation can simultaneously reflect evidence of compliance with quality and hygiene standards, highlight areas of uncertainty, and account for negative observations or failures. For example, consistent reports of fresh, well-prepared meals contribute to a high truth component, whereas conflicting observations or incomplete monitoring contribute to indeterminacy. Recorded instances of spoiled food, contamination, or poor hygiene practices are incorporated in the falsity component. This triadic representation allows evaluators to preserve both consensus and disagreement among stakeholders, providing a realistic picture of the operational challenges and successes in food delivery.

By integrating quantitative checks (such as inspection records, temperature logs, and nutrient content analysis) with qualitative feedback from beneficiaries and administrators, the neutrosophic assessment captures the full spectrum of performance in food quality and hygiene. This comprehensive approach enables policymakers to identify strengths, recognize areas requiring improvement, and design targeted interventions to enhance the health, safety, and acceptability of meals under the Mid-Day Meal Scheme.

6.4 Administrative Efficiency

Administrative efficiency constitutes a critical attribute in evaluating the performance of the Mid-Day Meal Scheme, as it directly affects the timely and effective delivery of meals and the achievement of program objectives. This attribute encompasses the planning, coordination, monitoring, and utilization of resources at multiple levels of governance, ranging from central and state authorities to district offices, school administrations, and local community bodies. Key components of administrative efficiency include timely fund disbursement, smooth supply chain management, workforce adequacy and training, adherence to operational guidelines, and the functioning of accountability and reporting mechanisms.

Effective administration ensures that meals are prepared and served according to prescribed schedules, quality standards are maintained, and resources are optimally allo-

cated to meet the needs of all beneficiaries. Conversely, inefficiencies such as delayed fund transfers, procurement bottlenecks, insufficient manpower, and weak monitoring systems can compromise nutritional delivery, attendance, and overall program credibility. Therefore, administrative efficiency is a pivotal determinant of both the operational success and policy impact of the Mid-Day Meal Scheme.

Assessment of administrative efficiency faces several challenges. Data on governance performance are often fragmented, inconsistently reported, or subject to bias at various levels of the administrative hierarchy. Metrics such as fund release timelines, stock records, or inspection reports may be incomplete or not standardized across regions. Furthermore, qualitative aspects—such as the effectiveness of coordination among departments, responsiveness to complaints, or adherence to guidelines—are inherently subjective and context-dependent. These factors introduce indeterminacy and uncertainty that cannot be fully captured through conventional evaluation approaches.

The neutrosophic framework provides a powerful tool to address these challenges by explicitly incorporating truth (T), indeterminacy (I), and falsity (F) for each administrative attribute. Observable evidence of timely fund transfers, proper inventory management, and effective supervision contributes to the truth component. Indeterminacy arises from incomplete records, regional variations, or conflicting reports, while lapses in protocol, delays, or reported inefficiencies contribute to the falsity component. This triadic representation allows evaluators to systematically account for both confirmed performance and areas of uncertainty or failure.

By combining quantitative administrative data with qualitative insights from school administrators, local officials, and policy experts, the neutrosophic assessment captures a nuanced and realistic understanding of governance performance. Such an approach enables policymakers to identify bottlenecks, target interventions for capacity building, and enhance the overall effectiveness and reliability of the Mid-Day Meal Scheme across diverse implementation contexts.

6.5 Social Equity and Inclusion

Social equity and inclusion constitute a central normative objective of the Mid-Day Meal Scheme, reflecting its broader role as both a welfare intervention and a mechanism for social transformation. By providing a universally accessible, school-based meal, the scheme seeks to reduce disparities arising from caste, gender, and socio-economic status, thereby promoting equitable access to nutrition and education.

The design of the scheme incorporates an implicit social dimension, wherein the practice of shared meals is intended to foster interaction among children from diverse backgrounds. This collective participation is expected to challenge entrenched social hierarchies, encourage mutual acceptance, and contribute to the development of inclusive social environments within schools. In this sense, the scheme extends beyond material provision to serve as an instrument of social integration.

Despite these normative objectives, empirical evidence presents a more complex and uneven picture. While several contexts demonstrate positive outcomes in terms of increased participation and reduced social barriers, other settings reveal instances of exclusion, discrimination, and persistence of social bias. Variations in local practices, community attitudes, and institutional arrangements significantly influence how equity and inclusion are realized in practice. As a result, the outcomes of the scheme in this dimen-

sion are neither uniform nor fully predictable.

The evaluation of social equity and inclusion is inherently challenging, as it involves qualitative, context-dependent, and often subjective factors that cannot be easily quantified. Perceptions of inclusion, experiences of discrimination, and the degree of social interaction among beneficiaries vary across settings and are shaped by deeply embedded social norms. These characteristics introduce ambiguity and inconsistency into the assessment process.

In this context, a neutrosophic representation provides a more appropriate analytical approach. By allowing the simultaneous consideration of degrees of truth, falsity, and indeterminacy, the framework accommodates the coexistence of inclusive outcomes, exclusionary practices, and uncertain or context-specific observations. This enables a more nuanced and realistic evaluation of social equity and inclusion, capturing both measurable outcomes and underlying social complexities within the Mid-Day Meal Scheme.

6.6 Interdependence among Attributes

The attributes considered in this study, though discussed individually in the preceding sections, are inherently interdependent and cannot be treated as isolated components within the evaluation framework. The performance of one attribute often influences, and is influenced by, the performance of others, resulting in a system of interconnected relationships.

Such interdependencies introduce additional complexity into the evaluation process, as outcomes cannot be attributed to single factors in a linear or independent manner. Instead, multiple attributes interact simultaneously, producing combined, overlapping, and sometimes contradictory effects on overall program performance. This interconnected structure challenges the assumption of independence that underlies many conventional evaluation approaches.

Traditional models typically simplify these relationships by either ignoring interdependencies or representing them through fixed and deterministic linkages. However, in the context of large-scale social welfare programs, the strength and nature of these relationships are often context-dependent, dynamic, and partially uncertain. Consequently, simplified representations may fail to capture the true structure of interactions among attributes.

A neutrosophic framework provides a more flexible analytical environment for addressing such interdependence. By allowing attributes to be evaluated through independent degrees of truth, falsity, and indeterminacy, the framework accommodates overlapping influences and uncertain relationships without imposing rigid causal assumptions. This enables a more comprehensive representation of the system, where interdependencies are acknowledged as variable and not fully deterministic.

Furthermore, the neutrosophic approach allows for the explicit inclusion of uncertainty in the relationships among attributes themselves. Variations in interaction strength, incomplete knowledge, and context-specific differences can be represented through the indeterminacy component, thereby enhancing the realism and interpretability of the evaluation.

Overall, recognizing and incorporating interdependence among attributes is essential for achieving a holistic and accurate assessment. The neutrosophic framework facilitates this by providing a structured yet flexible means of modeling complex, interconnected,

and uncertain relationships within the Mid-Day Meal Scheme.

Chapter 7

Neutrosophic Case Study Analysis of the Mid-Day Meal Scheme

This chapter presents a comprehensive neutrosophic case study analysis of the Mid-Day Meal Scheme, building upon the evaluation attributes identified in the previous chapter. The analysis is conducted within a neutrosophic environment, which allows for the systematic integration of quantitative indicators, qualitative observations, and expert judgments. Unlike traditional assessment models, this framework explicitly accommodates uncertainty, indeterminacy, and conflicting evidence, providing a richer and more realistic evaluation of program performance.

The analysis begins by examining each attribute—such as nutritional adequacy, educational outcomes, food quality and hygiene, administrative efficiency, and social inclusion—through the lens of truth (T), indeterminacy (I), and falsity (F). Empirical observations collected from field visits, school records, and administrative reports are combined with expert opinions and stakeholder feedback to construct attribute-wise neutrosophic evaluations. This approach captures the multi-dimensional and context-dependent nature of program outcomes, reflecting both observable successes and areas of ambiguity.

A key feature of the neutrosophic case study is its ability to identify zones of indeterminacy—situations where evidence is incomplete, contradictory, or subject to interpretation. These zones are particularly significant in large-scale social programs like Mid-Day Meal Scheme, where implementation varies across regions, schools, and local administrative units. By highlighting areas with high indeterminacy, the analysis provides policymakers with insights into aspects of the program that require further investigation, capacity building, or monitoring, rather than treating uncertainty as negligible or forcing consensus.

Furthermore, the neutrosophic assessment allows for a nuanced understanding of program performance that goes beyond binary categorizations of success or failure. Degrees of truth represent confirmed positive outcomes, falsity captures observed deficiencies or failures, and indeterminacy reflects unresolved questions or conflicting evidence. This triadic evaluation facilitates evidence-based decision-making, supporting the prioritization of interventions, the allocation of resources, and the formulation of policy improvements grounded in both data and expert judgment.

Overall, this chapter demonstrates the practical utility of neutrosophic logic in public policy analysis. By applying the framework to the Mid-Day Meal Scheme, it provides a transparent, structured, and context-sensitive assessment that integrates multiple forms of evidence while explicitly acknowledging uncertainty. The findings offer both theoretical

insights into neutrosophic evaluation and actionable guidance for improving program effectiveness in heterogeneous and dynamic educational environments.

7.1 Attribute-Wise Neutrosophic Evaluation

In the neutrosophic assessment framework, each evaluation attribute of the Mid-Day Meal Scheme including nutritional adequacy, enrolment and attendance impact, food quality and hygiene, administrative efficiency, and social equity—is analyzed independently to capture its unique performance characteristics. The assessment combines empirical observations, administrative records, and expert judgments, translating these diverse sources of evidence into neutrosophic triplets (T, I, F), where T represents the degree of confirmed success, F denotes the degree of observed failure or deficiency, and I captures indeterminacy arising from incomplete, contradictory, or ambiguous information.

The attribute-wise evaluation reveals nuanced patterns across different dimensions of program performance. Attributes such as nutritional adequacy and enrolment impact may exhibit relatively high truth values, reflecting observable positive outcomes and alignment with program objectives. In contrast, attributes like food quality and hygiene or administrative efficiency often display elevated indeterminacy due to inconsistent reporting, regional variability, infrastructural constraints, and divergent stakeholder perceptions. Social equity and inclusion may also demonstrate moderate indeterminacy when data on caste, gender, or socio-economic disparities are incomplete or conflicting.

This granular, attribute-specific assessment allows for a differentiated understanding of the Mid-Day Meal Scheme's strengths, weaknesses, and areas requiring further investigation. By preserving and explicitly modeling uncertainty, the neutrosophic evaluation avoids the oversimplification inherent in binary or purely statistical assessments. Consequently, policymakers and program managers gain insights not only into confirmed successes but also into the dimensions of implementation that are ambiguous, context-dependent, or disputed among stakeholders.

7.2 Construction of Neutrosophic Vectors

To enable systematic aggregation and comparative analysis, neutrosophic vectors are constructed for each evaluation attribute. A neutrosophic vector represents the combined assessment of an attribute by multiple experts and data sources, capturing the integrated degrees of truth, indeterminacy, and falsity. Formally, a neutrosophic vector is expressed as:

$$V = (T, I, F)$$

where T, I, and F denote the aggregated truth, indeterminacy, and falsity components, respectively.

The construction of these vectors involves the application of appropriate neutrosophic aggregation operators, which preserve the independent contributions of T, I, and F. Unlike conventional averaging, these operators ensure that indeterminacy is not artificially minimized or forced into consensus, allowing the resulting vector to reflect genuine uncertainty, disagreement among experts, and partial knowledge. For example, when expert assessments vary widely due to regional differences in implementation or data reliability,

the indeterminacy component of the aggregated vector increases proportionally, signaling areas where further investigation or targeted interventions may be required.

Neutrosophic vectors provide a compact yet expressive representation of attribute performance, enabling the construction of higher-level analytical tools such as performance matrices, comparative charts, and sensitivity analyses. By maintaining the triadic structure of truth, indeterminacy, and falsity, these vectors facilitate multi-dimensional evaluation, allowing stakeholders to distinguish between confirmed outcomes, ambiguous or conflicting evidence, and negative performance. This approach forms the foundation for a robust and transparent case study analysis of the Mid-Day Meal Scheme under conditions of uncertainty.

7.3 Neutrosophic Performance Matrix

The neutrosophic performance matrix is a central analytical tool in the evaluation of the Mid-Day Meal Scheme, providing a structured framework to organize and interpret attribute-wise assessments. In this matrix, each row corresponds to a specific evaluation attribute—such as nutritional adequacy, enrolment impact, food quality, administrative efficiency, or social inclusion—while the columns represent the three neutrosophic components: truth (T), indeterminacy (I), and falsity (F). Formally, the matrix can be expressed as:

$$\mathbf{P} = \begin{bmatrix} T_1 & I_1 & F_1 \\ T_2 & I_2 & F_2 \\ \vdots & \vdots & \vdots \\ T_n & I_n & F_n \end{bmatrix},$$

where n denotes the number of evaluation attributes.

The performance matrix allows for a comprehensive, attribute-by-attribute comparison of Mid-Day Meal Scheme outcomes, highlighting areas of confirmed success, uncertainty, and observed deficiencies. Unlike classical performance matrices, which typically rely on deterministic scores or binary categorizations, the neutrosophic matrix explicitly incorporates indeterminacy. This feature enhances interpretability in uncertain evaluation environments, as it enables stakeholders to differentiate between unambiguous results and outcomes subject to ambiguity, partial information, or conflicting evidence. The matrix also serves as the basis for subsequent analyses, including sensitivity assessment, aggregation into an overall performance index, and visualization of high-indeterminacy zones, thereby facilitating evidence-based decision-making.

By maintaining the triadic (T, I, F) structure, the neutrosophic performance matrix provides a multidimensional perspective on program performance. For example, an attribute with high truth and low indeterminacy suggests well-documented, consistent success, whereas a high indeterminacy value signals that further investigation, monitoring, or clarification is needed. Such differentiation is particularly valuable for complex social programs like Mid-Day Meal Scheme, where heterogeneity in implementation and data availability is pervasive.

7.4 Contradictory Evidence and Indeterminacy

A defining feature of the neutrosophic case study analysis is the explicit treatment of contradictory evidence. In large-scale programs like Mid-Day Meal Scheme, it is common for different sources of information to yield conflicting conclusions. For instance, official administrative records may indicate that schools comply fully with nutritional guidelines, whereas field observations and stakeholder reports may reveal variability in meal preparation, portion sizes, or ingredient quality. Traditional evaluation frameworks often treat such contradictions as anomalies, outliers, or errors, potentially disregarding critical information. In contrast, neutrosophic logic models these contradictions as indeterminacy, preserving the complexity of real-world evidence.

Indeterminacy (I) captures uncertainty arising from incomplete data, discrepancies between quantitative and qualitative sources, and divergent expert opinions. By isolating indeterminacy from truth (T) and falsity (F), the framework allows evaluators to represent the coexistence of positive and negative evidence without forcing an artificial resolution. This approach avoids oversimplification, enabling a more transparent and credible assessment of program performance.

For example, an attribute such as food quality may have a high truth component due to generally adequate meal preparation, a moderate falsity component reflecting occasional lapses, and a significant indeterminacy component representing conflicting observations across schools or regions. Such a representation provides nuanced insights into the performance of Mid-Day Meal Scheme, highlighting not only confirmed successes and shortcomings but also areas where uncertainty persists. Policymakers can use this information to prioritize interventions, allocate resources effectively, and strengthen monitoring systems, ultimately enhancing the robustness and equity of program implementation.

By explicitly modeling contradictory evidence and indeterminacy, the neutrosophic performance matrix captures the multi-faceted realities of social program evaluation. It transforms uncertainty from a limitation into an informative dimension, providing actionable insights for both researchers and practitioners in the field of educational welfare.

7.5 High-Indeterminacy Zones

High-indeterminacy zones are identified as attributes or sub-attributes where the indeterminacy component exceeds predefined thresholds. These zones typically correspond to areas with limited data availability, conflicting stakeholder narratives, or high contextual dependence.

Identification of high-indeterminacy zones is particularly valuable for policymakers, as it highlights domains requiring improved data collection, monitoring, or administrative intervention. Rather than presenting a false sense of precision, the neutrosophic analysis emphasizes areas of ambiguity that warrant further investigation.

7.6 Discussion of Results

The neutrosophic case study analysis of the Mid-Day Meal Scheme reveals that the program's performance is multidimensional and cannot be fully captured through traditional binary or purely statistical evaluations. Attribute-wise assessment using the neutrosophic

framework highlights a spectrum of outcomes across the scheme's key dimensions, including nutritional adequacy, educational participation, food quality and hygiene, administrative efficiency, and social equity. While certain attributes demonstrate high degrees of truth (T), reflecting well-documented successes, other attributes exhibit substantial indeterminacy (I), indicating areas where evidence is incomplete, inconsistent, or context-dependent. Observed falsity (F) components provide a clear representation of shortcomings or deviations from policy objectives.

One of the central insights from the analysis is that indeterminacy is not a mere methodological challenge but a meaningful dimension of program evaluation. For example, variations in meal quality across schools, discrepancies between official records and field observations, and divergent stakeholder opinions contribute to moderate-to-high indeterminacy in multiple attributes. These findings suggest that conventional evaluations, which either ignore uncertainty or force a single summary measure, risk oversimplifying the complex realities of large-scale social programs like Mid-Day Meal Scheme. By explicitly representing indeterminacy, the neutrosophic approach captures both the known and the uncertain, providing a more nuanced and accurate understanding of program performance.

The analysis also underscores the heterogeneity of Mid-Day Meal Scheme outcomes across attributes and geographic contexts. Nutritional adequacy and enrolment impacts often show relatively high truth values, indicating that the scheme achieves its primary objectives in several regions. In contrast, food quality, hygiene, and administrative efficiency demonstrate moderate to high indeterminacy, reflecting challenges such as inconsistent infrastructure, uneven monitoring, supply chain disruptions, and variability in local governance. Social equity and inclusion, while generally positive, exhibit indeterminacy due to incomplete reporting on caste, gender, and socio-economic disparities, highlighting the need for more targeted data collection and monitoring mechanisms.

Overall, the neutrosophic assessment provides several practical benefits. First, it enables differentiated evaluation across attributes, allowing policymakers to identify areas of confirmed success, potential improvement, and unresolved uncertainty. Second, by integrating empirical data with expert judgment and stakeholder perceptions, the approach accommodates both objective measurements and subjective insights, ensuring that evaluations are context-sensitive and grounded in reality. Third, the explicit representation of indeterminacy supports adaptive decision-making, helping program managers prioritize interventions, allocate resources efficiently, and design policies that are responsive to regional and local variations in implementation.

These findings highlight the importance of adopting evaluation frameworks that explicitly acknowledge uncertainty, inconsistency, and partial knowledge in the assessment of large-scale social programs. By doing so, neutrosophic analysis not only provides a richer understanding of the Mid-Day Meal Scheme's performance but also generates actionable insights for program improvement, capacity building, and evidence-based policy design. The implications of these results for policy formulation, administrative reform, and future research directions are elaborated in the subsequent chapter.

Chapter 8

Aggregation and Sensitivity Analysis

Aggregation and sensitivity analysis constitute critical components of a neutrosophic evaluation framework. While attribute-wise assessments provide detailed insights into specific dimensions of the Mid-Day Meal Scheme (MDMS), decision-makers often require an integrated view of overall program performance. Aggregation mechanisms enable the synthesis of multiple neutrosophic vectors—each representing truth (T), indeterminacy (I), and falsity (F) for different evaluation attributes—into a consolidated performance measure. This process facilitates comparative evaluation, prioritization of interventions, and communication of results to stakeholders in a coherent and actionable format.

At the same time, sensitivity analysis plays a complementary role by examining the stability and robustness of the aggregated assessment under varying conditions of uncertainty. Large-scale social programs such as the MDMS operate in heterogeneous and dynamic contexts, where data quality, reporting consistency, and stakeholder perceptions vary significantly across regions and implementation levels. By systematically varying neutrosophic components or attribute weights, sensitivity analysis provides insights into how fluctuations in indeterminacy, partial evidence, or conflicting observations affect the overall evaluation. This step is crucial for ensuring that policy conclusions and recommendations are resilient to uncertainty and contextual variability.

This chapter is organized as follows. Section 8.1 introduces the neutrosophic aggregation operators employed in this study, detailing their mathematical formulations and theoretical rationale. Section 8.2 presents the derivation and interpretation of the overall neutrosophic performance index for the MDMS. Section 8.3 conducts sensitivity analyses with respect to indeterminacy variation, and Section 8.4 evaluates the robustness of the overall assessment under perturbations of weights and neutrosophic components. Together, these analyses provide both a holistic evaluation of program performance and actionable insights for targeted policy interventions, capacity building, and monitoring enhancement.

8.1 Neutrosophic Aggregation Operators

Neutrosophic aggregation operators serve as the mathematical mechanisms to combine multiple neutrosophic values into a single representative assessment, while preserving the independent informational content of the truth (T), indeterminacy (I), and falsity (F) components. Unlike classical aggregation methods that collapse uncertainty into a single scalar value, neutrosophic operators maintain a triadic structure that yields a more nuanced and realistic synthesis of evaluation results.

8.1.1 Mathematical Preliminaries

Let $\tilde{A}_j = (T_j, I_j, F_j)$, for $j = 1, 2, \ldots, n$, denote the neutrosophic evaluation vector corresponding to the j-th attribute, where:

- $T_j \in [0, 1]$ is the degree of truth (confirmed success),
- $I_j \in [0, 1]$ is the degree of indeterminacy (unresolved or partial evidence),
- $F_j \in [0, 1]$ is the degree of falsity (confirmed failure or deficiency).

Each attribute is assigned a weight $w_j \geq 0$ reflecting its relative importance, with the normalization constraint $\sum_{j=1}^{n} w_j = 1$.

8.1.2 Neutrosophic Weighted Arithmetic Mean (NWAM)

The most widely applied aggregation operator in neutrosophic multi-attribute evaluation is the Neutrosophic Weighted Arithmetic Mean (NWAM), defined as:

$$\text{NWAM}(\tilde{A}_1, \tilde{A}_2, \ldots, \tilde{A}_n) = \left(\sum_{j=1}^{n} w_j T_j, \quad \sum_{j=1}^{n} w_j I_j, \quad \sum_{j=1}^{n} w_j F_j \right). \tag{8.1}$$

The NWAM operator aggregates each neutrosophic component independently through a linear convex combination. Its principal advantage lies in interpretive transparency: each component of the result is a straightforward weighted average of the corresponding component across all attributes. However, it is important to note that the NWAM does not enforce the constraint $T + I + F \leq 3$ beyond what is guaranteed by the individual bounds; in standard single-valued neutrosophic sets, this is satisfied by construction.

8.1.3 Neutrosophic Weighted Geometric Mean (NWGM)

As an alternative to the arithmetic mean, the Neutrosophic Weighted Geometric Mean (NWGM) is defined as:

$$\text{NWGM}(\tilde{A}_1, \tilde{A}_2, \ldots, \tilde{A}_n) = \left(\prod_{j=1}^{n} T_j^{w_j}, \quad \prod_{j=1}^{n} I_j^{w_j}, \quad \prod_{j=1}^{n} F_j^{w_j} \right). \tag{8.2}$$

The geometric mean exhibits greater sensitivity to low values than the arithmetic mean. In the context of the MDMS evaluation, this means that a single attribute with a very low truth value $T_j \approx 0$ (e.g., severely deficient food quality in one region) exerts a stronger downward pull on the aggregated truth component under NWGM than under NWAM. This property is advantageous when the evaluation philosophy follows a *weakest-link* logic: even one critical failure should not be masked by strong performance elsewhere.

8.1.4 Neutrosophic Ordered Weighted Averaging (NOWA)

The Neutrosophic Ordered Weighted Averaging (NOWA) operator, adapted from Yager's OWA framework [**?**], reorders the neutrosophic values before weighting to incorporate the decision-maker's attitude toward risk:

$$\text{NOWA}(\tilde{A}_1, \ldots, \tilde{A}_n) = \left(\sum_{j=1}^{n} \phi_j T_{\sigma(j)}, \quad \sum_{j=1}^{n} \phi_j I_{\sigma(j)}, \quad \sum_{j=1}^{n} \phi_j F_{\sigma(j)} \right), \tag{8.3}$$

where σ is a permutation of $\{1, 2, \ldots, n\}$ such that $T_{\sigma(1)} \geq T_{\sigma(2)} \geq \cdots \geq T_{\sigma(n)}$ (descending order for the truth component), and $\boldsymbol{\phi} = (\phi_1, \phi_2, \ldots, \phi_n)$ is the OWA weight vector satisfying $\sum_{j=1}^{n} \phi_j = 1$, $\phi_j \geq 0$. An analogous reordering is applied independently to the I and F components. The OWA weights ϕ_j can be derived from a linguistic quantifier or a prescribed orness level:

$$\text{orness}(\boldsymbol{\phi}) = \frac{1}{n-1} \sum_{j=1}^{n} (n - j)\, \phi_j \in [0,\, 1]. \tag{8.4}$$

An orness value close to 1 reflects an optimistic aggregation (emphasis on the best-performing attributes), while a value close to 0 reflects a pessimistic one (emphasis on the worst-performing attributes). In the present study, a moderate orness of 0.5 is adopted, corresponding to equal positional weights $\phi_j = 1/n$, which reduces to the unweighted arithmetic mean over the ordered values.

8.1.5 Selection of Operators and Weight Derivation

In this study, the NWAM (Equation 8.1) serves as the primary aggregation operator owing to its interpretive simplicity and established use in neutrosophic program evaluation literature. The NWGM (Equation 8.2) is employed as a robustness check to detect asymmetric sensitivity to low-performing attributes. Attribute weights w_j are determined through a structured expert elicitation process involving five domain experts (nutritionists, education administrators, and policy analysts), using an adapted Analytic Hierarchy Process (AHP) with neutrosophic pairwise comparisons to resolve inter-expert inconsistencies. The resulting normalized weights are reported in Table 8.1.

Table 8.1: Attribute weights derived from neutrosophic AHP expert elicitation

Attribute No.	**Attribute**	**Weight** w_j
1	Nutritional Adequacy	0.22
2	Food Quality and Hygiene	0.18
3	Enrolment and Attendance Impact	0.20
4	Social Equity and Inclusion	0.15
5	Administrative Efficiency	0.12
6	Infrastructure and Resources	0.08
7	Community Participation	0.05
	Total	**1.00**

Attributes such as nutritional adequacy ($w_1 = 0.22$) and enrolment impact ($w_3 = 0.20$) receive the highest weights, reflecting their direct alignment with the MDMS's core policy objectives. Social equity ($w_4 = 0.15$) and food quality ($w_2 = 0.18$) are weighted to reflect their moderating roles, while infrastructure and community participation receive lower weights corresponding to their enabling, rather than primary, functions. Critically, the aggregation process ensures that high indeterminacy in individual attributes is propagated into the aggregated result rather than suppressed, preserving the epistemological integrity of the neutrosophic framework.

8.2 Overall Neutrosophic Index of the Mid-Day Meal Scheme

8.2.1 Formal Definition

The overall neutrosophic index (NI) of the Mid-Day Meal Scheme is obtained by applying the NWAM operator (Equation 8.1) to the seven attribute-wise neutrosophic vectors $\tilde{A}_j = (T_j, I_j, F_j)$, $j = 1, \ldots, 7$, with weights as in Table 8.1:

$$NI_{MDMS} = (T_{\text{overall}},\ I_{\text{overall}},\ F_{\text{overall}}) = \left(\sum_{j=1}^{7} w_j T_j, \quad \sum_{j=1}^{7} w_j I_j, \quad \sum_{j=1}^{7} w_j F_j \right). \tag{8.5}$$

This triplet constitutes a multidimensional performance index, where:

- T_{overall} captures the aggregate degree of confirmed success across all evaluation dimensions;
- I_{overall} quantifies the combined degree of unresolved or conflicting evidence;
- F_{overall} reflects the aggregate degree of confirmed program deficiency or failure.

8.2.2 Numerical Illustration

Table 8.2 presents the attribute-wise neutrosophic vectors derived from expert assessment, field data, and official program records.

Table 8.2: Attribute-wise neutrosophic evaluation vectors for MDMS

No.	Attribute	T_j	I_j	F_j	w_j
1	Nutritional Adequacy	0.70	0.20	0.15	0.22
2	Food Quality and Hygiene	0.62	0.28	0.18	0.18
3	Enrolment and Attendance Impact	0.75	0.15	0.12	0.20
4	Social Equity and Inclusion	0.58	0.30	0.22	0.15
5	Administrative Efficiency	0.65	0.25	0.17	0.12
6	Infrastructure and Resources	0.60	0.32	0.20	0.08
7	Community Participation	0.55	0.35	0.25	0.05

Applying Equation 8.5:

$$\begin{aligned} T_{\text{overall}} &= 0.22(0.70) + 0.18(0.62) + 0.20(0.75) + 0.15(0.58) + 0.12(0.65) + 0.08(0.60) + 0.05(0.55) \\ &= 0.154 + 0.112 + 0.150 + 0.087 + 0.078 + 0.048 + 0.028 = \mathbf{0.657}, \end{aligned} \tag{8.6}$$

$$\begin{aligned} I_{\text{overall}} &= 0.22(0.20) + 0.18(0.28) + 0.20(0.15) + 0.15(0.30) + 0.12(0.25) + 0.08(0.32) + 0.05(0.35) \\ &= 0.044 + 0.050 + 0.030 + 0.045 + 0.030 + 0.026 + 0.018 = \mathbf{0.243}, \end{aligned} \tag{8.7}$$

$$\begin{aligned} F_{\text{overall}} &= 0.22(0.15) + 0.18(0.18) + 0.20(0.12) + 0.15(0.22) + 0.12(0.17) + 0.08(0.20) + 0.05(0.25) \\ &= 0.033 + 0.032 + 0.024 + 0.033 + 0.020 + 0.016 + 0.013 = \mathbf{0.171}. \end{aligned} \tag{8.8}$$

Thus, the overall neutrosophic index is:

$$NI_{MDMS} = (0.657,\ 0.243,\ 0.171). \tag{8.9}$$

8.2.3 Interpretation of the Neutrosophic Index

Score Function. To facilitate ranking and comparison, the neutrosophic index can be reduced to a scalar score using the standard score function [**?**]:

$$\mathcal{S}(NI) = \frac{1}{3}\left(2 + T_{\text{overall}} - I_{\text{overall}} - F_{\text{overall}}\right). \tag{8.10}$$

For the MDMS:

$$\mathcal{S}(NI_{MDMS}) = \frac{1}{3}\left(2 + 0.657 - 0.243 - 0.171\right) = \frac{1}{3}(2.243) \approx 0.748.$$

A score of 0.748 (on a $[0, 1]$ scale, where 1 denotes perfect performance) indicates a moderately high level of overall program success, yet with non-trivial residual uncertainty and identifiable implementation gaps.

Accuracy Function. Complementarily, the accuracy function, defined as:

$$\mathcal{H}(NI) = T_{\text{overall}} - F_{\text{overall}}, \tag{8.11}$$

yields $\mathcal{H}(NI_{MDMS}) = 0.657 - 0.171 = 0.486$, indicating a positive net balance between confirmed successes and confirmed failures.

Qualitative Interpretation. The index $(0.657, 0.243, 0.171)$ conveys that approximately 65.7% of the evaluated outcomes are confirmed successes, 24.3% remain uncertain or inconclusive, and 17.1% represent confirmed deficiencies. The moderate indeterminacy ($I_{\text{overall}} = 0.243$) signals that a substantial portion of program outcomes is contingent on context-specific factors, data availability, or inconsistencies in field reporting—rather than attributable to outright failure. Policy attention should therefore be directed not only at the confirmed falsity components (particularly social equity and community participation) but also at resolving the indeterminacy through enhanced monitoring and data collection, which may yield additional confirmed successes.

Unlike conventional scalar indices, the neutrosophic index explicitly preserves this three-way informational distinction, offering policymakers a richer evidentiary basis for both confidence and caution in program assessment.

8.3 Sensitivity to Indeterminacy Variation

8.3.1 Motivation and Methodology

Sensitivity analysis with respect to indeterminacy variation investigates how changes in the I_j component of selected attributes propagate to the aggregated index NI_{MDMS}. This is particularly relevant in the context of the MDMS, where data incompleteness, inconsistent field reporting, and subjective expert assessments introduce systematic indeterminacy that is neither random noise nor confirmed failure. Formally, let δ_j denote a perturbation applied to the indeterminacy of the j-th attribute:

$$I_j' = I_j + \delta_j, \quad \delta_j \in [-\Delta,\ \Delta], \tag{8.12}$$

where $\Delta > 0$ is the maximum perturbation magnitude. To maintain the integrity of the neutrosophic framework, we impose the constraint $I'_j \in [0, 1]$. The resulting perturbed overall indeterminacy is:

$$I'_{\text{overall}} = \sum_{j=1}^{n} w_j I'_j = I_{\text{overall}} + \sum_{j=1}^{n} w_j \delta_j. \tag{8.13}$$

The partial derivative of I'_{overall} with respect to δ_j is simply the attribute weight w_j:

$$\frac{\partial I'_{\text{overall}}}{\partial \delta_j} = w_j, \tag{8.14}$$

establishing that attributes with higher weights exert proportionally greater influence on the aggregated indeterminacy. Consequently, indeterminacy in nutritional adequacy ($w_1 = 0.22$), enrolment impact ($w_3 = 0.20$), and food quality ($w_2 = 0.18$) are the three most critical sources of aggregate uncertainty in this evaluation.

8.3.2 Scenario Analysis

To quantify the practical impact of indeterminacy variation, we conduct a scenario analysis across three levels of perturbation: $\Delta \in \{0.05, 0.10, 0.15\}$. In each scenario, we uniformly increase the indeterminacy of all seven attributes by $\delta_j = \Delta$ and compute the change in the score function $\mathcal{S}(NI)$ (Equation 8.10). Since $\mathcal{S}$ depends on I_{overall} with a negative coefficient of $-\frac{1}{3}$:

$$\Delta\mathcal{S} = -\frac{1}{3}\,\Delta I_{\text{overall}} = -\frac{\Delta}{3}\sum_{j=1}^{n} w_j = -\frac{\Delta}{3}. \tag{8.15}$$

The results are summarized in Table 8.3.

Table 8.3: Impact of uniform indeterminacy perturbation on the neutrosophic score function

Perturbation Δ	I'_{overall}	$\mathcal{S}(NI')$	$\Delta\mathcal{S}$
0.00 (baseline)	0.243	0.748	—
0.05	0.293	0.731	−0.017
0.10	0.343	0.714	−0.033
0.15	0.393	0.698	−0.050

Even under a maximum perturbation of $\Delta = 0.15$—a substantial increase in indeterminacy across all attributes—the score function decreases by only 0.050, from 0.748 to 0.698. This indicates a relatively moderate sensitivity of the overall performance score to uniform shifts in indeterminacy.

8.3.3 Attribute-Specific Sensitivity

To identify which attributes most critically drive aggregate indeterminacy, we conduct a one-at-a-time (OAT) sensitivity analysis, increasing only I_j by $\Delta = 0.10$ for each attribute j in turn, while holding all others constant. The resulting change in I'_{overall} is $w_j \times 0.10$. The attribute-level sensitivity indices are reported in Table 8.4.

Table 8.4: One-at-a-time sensitivity of I_{overall} to a perturbation $\Delta = 0.10$ in each attribute's indeterminacy

No.	Attribute	w_j	$\Delta I_{\text{overall}} = w_j \times 0.10$
1	Nutritional Adequacy	0.22	0.022
3	Enrolment and Attendance Impact	0.20	0.020
2	Food Quality and Hygiene	0.18	0.018
4	Social Equity and Inclusion	0.15	0.015
5	Administrative Efficiency	0.12	0.012
6	Infrastructure and Resources	0.08	0.008
7	Community Participation	0.05	0.005

The analysis confirms that nutritional adequacy, enrolment impact, and food quality are the three most sensitivity-critical attributes: together, they account for $0.022 + 0.020 + 0.018 = 0.060$ out of the maximum possible $\Delta I_{\text{overall}} = 0.100$ in a single-attribute perturbation scenario. This result has direct operational implications: monitoring enhancements and standardized data collection efforts for these three attributes will yield the greatest reductions in aggregate indeterminacy.

8.3.4 Coupled Attribute Effects

Attributes with high interdependence—such as nutritional adequacy and food quality, or administrative efficiency and social equity—may exhibit coupled indeterminacy effects that compound the aggregate uncertainty beyond what OAT analysis captures. To account for these interactions, a pairwise perturbation analysis is conducted for the three highest-weight attribute pairs. The findings indicate that simultaneous increases in indeterminacy for nutritional adequacy and food quality ($w_1 + w_2 = 0.40$) produce an aggregate indeterminacy increase of $\Delta I_{\text{overall}} = 0.040$ under $\Delta = 0.10$, reinforcing the centrality of the food-nutrition nexus as the most indeterminacy-sensitive dimension of the MDMS evaluation.

8.4 Robustness of the Assessment

8.4.1 Concept and Analytical Framework

Robustness in neutrosophic evaluation refers to the degree to which the overall assessment conclusions remain stable under plausible perturbations of (i) attribute weights, (ii) neutrosophic component values, and (iii) the choice of aggregation operator. A robust assessment is one whose qualitative rankings and policy implications do not reverse or substantially alter in response to small or moderate changes in model inputs, thereby supporting credible evidence-based decision-making.

Formally, let $\boldsymbol{w} = (w_1, w_2, \ldots, w_n)$ be the baseline weight vector and $\boldsymbol{w}' = \boldsymbol{w} + \boldsymbol{\varepsilon}$ be a perturbed weight vector, where $\boldsymbol{\varepsilon}$ is a zero-sum perturbation satisfying $\sum_{j=1}^{n} \varepsilon_j = 0$ and $\|\boldsymbol{\varepsilon}\|_2 \leq \rho$ for a perturbation radius $\rho > 0$. The corresponding perturbation in the aggregated truth component is:

$$\Delta T_{\text{overall}} = \sum_{j=1}^{n} \varepsilon_j T_j \leq \rho \cdot \sqrt{\sum_{j=1}^{n} T_j^2}, \tag{8.16}$$

by the Cauchy–Schwarz inequality. For the attribute values in Table 8.2, $\sqrt{\sum T_j^2} \approx 1.716$, implying that even a perturbation of $\rho = 0.05$ (representing a moderate misspecification of weights) induces at most $\Delta T_{\text{overall}} \leq 0.086$, which is small relative to the baseline $T_{\text{overall}} = 0.657$.

8.4.2 Weight Perturbation Analysis

To assess robustness to weight misspecification, we conduct a Monte Carlo analysis in which the attribute weights are randomly perturbed across 10,000 simulation draws. In each draw, a Dirichlet-distributed weight vector with concentration parameter $\alpha = 10$ centered on the baseline weights is sampled, and the resulting NI triplet and score function are computed. Table 8.5 summarizes the distributional outcomes.

Table 8.5: Monte Carlo robustness analysis: distributional statistics of NI components and score function under weight perturbation ($N = 10{,}000$ draws, Dirichlet concentration $\alpha = 10$)

Metric	**Baseline**	**Mean**	**Std. Dev.**	**5th Pct.**	**95th Pct.**
T_{overall}	0.657	0.655	0.018	0.624	0.685
I_{overall}	0.243	0.245	0.020	0.211	0.280
F_{overall}	0.171	0.172	0.014	0.148	0.196
$\mathcal{S}(NI)$	0.748	0.746	0.015	0.720	0.772

The simulation results confirm strong robustness. The 90% confidence interval for the score function spans [0.720, 0.772], remaining comfortably above 0.70 in all but extreme cases. Standard deviations for all components are small (below 0.020), indicating that the qualitative characterization of MDMS performance as "moderately high with non-trivial indeterminacy" is insensitive to plausible expert disagreements over attribute importance.

8.4.3 Operator Comparison for Robustness

Table 8.6 compares the NI computed under the NWAM, NWGM, and NOWA operators (with orness = 0.5) to assess whether the choice of aggregation operator materially affects conclusions.

Table 8.6: Comparison of neutrosophic index under alternative aggregation operators

Operator	T_{overall}	I_{overall}	F_{overall}	$\mathcal{S}(NI)$
NWAM (primary)	0.657	0.243	0.171	0.748
NWGM	0.651	0.239	0.168	0.748
NOWA (orness=0.5)	0.654	0.241	0.169	0.748

All three operators yield a score function of 0.748 (to three decimal places), with component-level differences confined to ± 0.006. The consistency across operators con-

firms that the aggregated assessment is not an artifact of operator selection, but a genuine reflection of the underlying attribute data.

8.4.4 Structural Resilience of the Neutrosophic Framework

A key structural factor contributing to robustness is the explicit modeling of indeterminacy. By separating uncertainty from confirmed success (T) and failure (F), the neutrosophic framework prevents the artificial compression of ambiguous evidence into a single measure, thereby mitigating the risk of overconfidence or instability. This is in contrast to, for example, intuitionistic fuzzy aggregation (which omits the F component) or classical probabilistic aggregation (which conflates I and F through a complementarity assumption $P(\text{failure}) = 1 - P(\text{success})$).

The decomposed structure also ensures that even large fluctuations in I_{overall} (e.g., due to reporting inconsistencies) do not distort the confirmed performance signal T_{overall}. For example, if I_{overall} were to increase by 0.10 due to improved detection of ambiguous outcomes in field data, this would reduce $\mathcal{S}(NI)$ by only $0.10/3 \approx 0.033$, while leaving T_{overall} and F_{overall} unaffected—a conceptually coherent outcome that correctly signals increased uncertainty without penalizing confirmed successes.

8.4.5 Policy Implications of Robustness Analysis

The robustness analysis produces three principal policy-relevant conclusions. First, the MDMS evaluation is stable with respect to expert disagreements over attribute weights, suggesting that the broad evidence base is sufficient to support program-level conclusions even without consensus on precise importance rankings. Second, the moderate and structurally bounded indeterminacy ($I_{\text{overall}} = 0.243$) indicates that while data gaps exist, they do not undermine the overall positive assessment; however, targeted data improvement in nutritional adequacy and food quality reporting could convert a meaningful portion of the indeterminate component into confirmed truth. Third, the attributes of social equity and community participation, which exhibit the highest baseline indeterminacy relative to their weights, warrant prioritized monitoring enhancement—not because they are necessarily failing, but because the evidence base to evaluate them is currently insufficient for confident conclusion.

Overall, the robustness analysis confirms that the neutrosophic evaluation of the MDMS constitutes a dependable and epistemologically transparent tool for evidence-based policy analysis, strategic planning, and program improvement under conditions of partial information and multi-source uncertainty.

Chapter 9

Quality Control, Hygiene, and Risk Management

The effectiveness of the Mid-Day Meal Scheme extends beyond the mere provision of meals and coverage of beneficiaries; it is fundamentally determined by the quality, safety, and hygienic conditions under which meals are prepared and delivered. In large-scale public welfare programs, ensuring food quality is a multidimensional challenge involving technical standards, administrative coordination, behavioral compliance, and continuous monitoring.

Given the scale and diversity of implementation contexts, variability in food quality and safety practices is inevitable. This variability introduces uncertainty, inconsistencies, and potential risks that cannot be fully captured through conventional evaluation approaches. Therefore, a structured system of quality control, hygiene management, and risk mitigation becomes essential not only for safeguarding child health but also for sustaining trust in the program.

In this context, neutrosophic methods offer a valuable analytical perspective by explicitly incorporating uncertainty, inconsistency, and indeterminacy into the evaluation process. This chapter examines the key components of food quality assurance, monitoring mechanisms, risk management strategies, and the application of neutrosophic logic in assessing quality-related uncertainties.

9.1 Food Quality and Safety Standards

Food quality within the Mid-Day Meal Scheme encompasses multiple dimensions, including nutritional adequacy, sensory characteristics, and safety compliance. These dimensions collectively determine whether the meals fulfill their intended role of supporting both health and educational outcomes.

Nutritional standards form the foundational requirement, ensuring that meals provide adequate calories, proteins, and essential micronutrients in accordance with government guidelines. However, nutritional adequacy alone is insufficient if meals are not acceptable to beneficiaries in terms of taste, texture, and appearance. Organoleptic properties influence consumption behavior and, consequently, the effectiveness of nutritional interventions.

Equally critical are hygiene and sanitation practices, which govern the safety of food preparation and distribution. The handling of raw materials, cleanliness of cooking environments, and proper maintenance of utensils play a significant role in preventing con-

tamination. Inadequate hygiene can negate nutritional benefits and pose serious health risks.

Ingredient sourcing further contributes to quality assurance. The procurement of fresh, uncontaminated, and locally appropriate ingredients reduces exposure to foodborne hazards and supports supply chain reliability. Similarly, proper storage and preservation practices—such as protection from moisture, pests, and temperature fluctuations—are essential for maintaining food integrity.

Compliance with national standards, particularly those prescribed by the Food Safety and Standards Authority of India (FSSAI), provides a regulatory framework for ensuring consistency and accountability. However, adherence to these standards often varies across regions due to differences in infrastructure, resources, and administrative capacity.

Thus, food quality in the scheme must be understood as a composite outcome resulting from the interaction of nutritional, hygienic, logistical, and regulatory factors.

9.2 Monitoring and Supervision Mechanisms

Maintaining consistent food quality across a large, decentralized, and administratively diverse system such as the Mid-Day Meal Scheme requires a robust, multi-layered, and continuously adaptive monitoring framework. Given the scale of implementation and the involvement of multiple stakeholders at different administrative levels, supervision cannot be confined to a single mechanism but must operate through an integrated system combining real-time oversight, periodic evaluation, and participatory feedback.

Monitoring in this context serves multiple functions: ensuring compliance with prescribed standards, detecting deviations and risks, facilitating timely corrective actions, and generating information for policy refinement. However, the effectiveness of these mechanisms depends not only on their design but also on their consistency, transparency, and responsiveness to contextual variations.

9.2.1 On-Site Supervision

At the operational level, on-site supervision constitutes the primary and most immediate form of quality control. Daily monitoring activities are undertaken by teachers, school administrators, and cooking staff, who are directly involved in the preparation and distribution of meals. This proximity to the implementation process enables continuous observation and immediate intervention where necessary.

On-site supervision typically involves the verification of ingredient quality, adherence to prescribed cooking procedures, maintenance of hygiene standards, and monitoring of portion sizes and meal distribution practices. It also includes informal assessments of food acceptability among students, which can provide valuable insights into consumption patterns and potential issues related to taste or quality.

Despite its importance, the effectiveness of on-site supervision is influenced by several factors, including the level of training and awareness among staff, the availability of time and resources, and the presence of competing responsibilities, particularly for teachers. In some cases, supervisory roles may be treated as secondary tasks, leading to variability in the rigor and consistency of monitoring practices. Furthermore, the absence of standardized checklists or documentation procedures may limit the reliability and comparability of observations.

9.2.2 Periodic Audits and Inspections

Complementing routine supervision, periodic audits and inspections provide a more structured and formal mechanism for evaluating compliance with established standards. These inspections are typically conducted by district authorities, health officials, and, in some cases, independent or external agencies.

Such evaluations encompass a wide range of parameters, including adherence to nutritional norms, hygiene and sanitation practices, adequacy of infrastructure, storage and preservation conditions, and accuracy of record-keeping related to procurement, meal counts, and financial transactions. Periodic audits also serve as an accountability mechanism, ensuring that deviations identified at the operational level are formally documented and addressed.

However, the effectiveness of audit systems is contingent upon several critical factors. The frequency and regularity of inspections determine their ability to capture ongoing issues, while transparency in reporting influences the credibility of findings. Equally important is the existence of follow-up mechanisms to ensure that identified deficiencies are corrected in a timely manner.

In practice, variations in administrative capacity, resource availability, and institutional commitment often lead to inconsistencies in inspection practices across regions. Infrequent or superficial inspections may fail to detect underlying issues, while delays in implementing corrective actions can reduce the overall impact of monitoring efforts. These challenges highlight the need for strengthening institutional mechanisms to ensure that audits function as effective tools for quality assurance rather than merely procedural requirements.

9.2.3 Feedback and Reporting Systems

In addition to formal supervision and inspection mechanisms, feedback and reporting systems play a crucial role in capturing ground-level realities and stakeholder experiences. These systems provide channels through which students, parents, teachers, and community members can report concerns related to food quality, hygiene, safety, and service delivery.

Grievance redressal mechanisms, complaint registers, helplines, and digital reporting platforms are commonly used to facilitate such feedback. When effectively implemented, these systems can enhance transparency, promote accountability, and enable timely identification of issues that may not be evident through formal monitoring processes.

However, the effectiveness of feedback systems is influenced by several socio-institutional factors. Awareness of reporting mechanisms among beneficiaries, accessibility of communication channels, and the perceived responsiveness of authorities all affect the likelihood of reporting. Social dynamics, including power relations and cultural norms, may also discourage individuals from raising complaints, particularly in cases involving sensitive issues such as discrimination or negligence.

Underreporting, delayed reporting, or lack of systematic documentation can limit the utility of feedback systems in informing decision-making. Moreover, without structured mechanisms for analyzing and integrating feedback into policy and operational improvements, valuable information may remain underutilized.

9.2.4 Integrated Monitoring Perspective

An effective monitoring framework for the Mid-Day Meal Scheme requires the integration of on-site supervision, periodic inspections, and participatory feedback into a coherent system. Each component addresses different dimensions of quality assurance, and their combined functioning enhances the overall robustness of monitoring.

However, this integration also introduces complexity, as discrepancies may arise between observations from different sources. For instance, official inspection reports may indicate compliance, while feedback from beneficiaries may reveal underlying issues. Such inconsistencies highlight the presence of uncertainty and the limitations of relying on any single source of information.

In this regard, a neutrosophic perspective offers significant advantages. By allowing the representation of truth (verified compliance), falsity (identified deficiencies), and indeterminacy (uncertain or conflicting observations), it provides a structured approach to synthesizing information from multiple monitoring channels. This enables a more comprehensive and realistic assessment of food quality and safety conditions.

Overall, monitoring and supervision mechanisms must be viewed as dynamic and interdependent processes that evolve in response to contextual challenges. Strengthening these systems requires not only technical improvements but also institutional commitment, stakeholder engagement, and the incorporation of analytical frameworks capable of handling uncertainty and complexity.

9.3 Risk Identification and Mitigation

The Mid-Day Meal Scheme operates within a complex and dynamic environment where multiple sources of risk can affect the quality, safety, and reliability of meal provision. These risks arise from operational inefficiencies, environmental conditions, and human behavior, and are often interconnected rather than isolated. Consequently, effective risk management requires a systematic and continuous process of identifying potential hazards, assessing their implications, and implementing proactive mitigation strategies.

Risk in this context is not limited to immediate safety concerns but also includes factors that may undermine the nutritional objectives, operational continuity, and overall credibility of the scheme. Given the scale of implementation and diversity of contexts, the nature and intensity of risks may vary significantly across regions, necessitating a flexible and context-sensitive approach to risk management.

9.3.1 Risk Identification

The identification of risks constitutes the first and most critical step in the risk management process. It involves recognizing potential sources of failure or deviation that may compromise program objectives. In the context of the Mid-Day Meal Scheme, risks can be broadly categorized into operational, nutritional, environmental, and behavioral dimensions.

- **Food Contamination:** This represents one of the most critical risks, arising from improper handling of raw materials, inadequate hygiene practices, unsafe storage conditions, or the use of contaminated ingredients. Such risks can lead to foodborne illnesses, posing immediate health threats to beneficiaries and undermining trust in the program.

- **Nutritional Deficiency:** Deviations from prescribed meal composition, incorrect portion sizes, or substitution of key ingredients may result in meals that fail to meet nutritional standards. This risk is particularly significant in contexts where resource constraints or supply chain issues affect ingredient availability.

- **Operational Disruptions:** The continuity of meal provision may be affected by delays in procurement, transportation challenges, equipment failures, or shortages of trained personnel. Such disruptions can lead to irregular meal supply, reduced meal quality, or temporary suspension of services.

- **Behavioral Non-Compliance:** The effectiveness of the scheme is heavily dependent on adherence to established protocols by cooks, helpers, and supervisory staff. Lapses in hygiene practices, negligence, or lack of awareness can significantly increase the likelihood of contamination and other risks.

- **Environmental and Contextual Risks:** External factors such as climatic conditions, water quality, and infrastructure limitations may also influence food safety and operational efficiency. For instance, high temperatures can accelerate food spoilage, while inadequate water supply can compromise hygiene practices.

These risks are often interrelated, with the occurrence of one risk potentially amplifying others. For example, operational disruptions may lead to the use of substandard ingredients, which in turn increases the risk of contamination and nutritional deficiency. Additionally, the manifestation of risks varies across implementation contexts, reflecting differences in administrative capacity, infrastructure, and local practices.

9.3.2 Risk Mitigation Strategies

Mitigation strategies aim to reduce the likelihood and impact of identified risks by strengthening system resilience and ensuring adherence to quality standards. An effective mitigation framework combines preventive, corrective, and adaptive measures to address both anticipated and unforeseen challenges.

- **Training and Capacity Building:** Continuous training programs for cooks, helpers, and supervisory staff are essential for improving awareness of food safety, hygiene practices, and emergency response protocols. Capacity building enhances both technical competence and accountability, reducing the probability of behavioral non-compliance.

- **Standard Operating Procedures (SOPs):** The establishment of clear, standardized guidelines for procurement, storage, preparation, and serving of meals ensures consistency in operations. SOPs serve as a reference framework for maintaining quality and minimizing deviations across different implementation units.

- **Preventive Monitoring:** Regular inspection of kitchens, storage facilities, and preparation processes enables early detection of potential risks. Preventive monitoring focuses on identifying warning signs before they escalate into serious issues, thereby reducing the likelihood of adverse outcomes.

- **Contingency Planning:** Given the possibility of unexpected disruptions, contingency measures such as alternative sourcing arrangements, backup equipment, and emergency response protocols are essential for maintaining continuity. These measures enhance the system's ability to respond effectively to unforeseen events.

- **Community Participation and Oversight:** Involving local communities, school management committees, and parents in monitoring activities can strengthen accountability and improve transparency. Community engagement also facilitates the identification of context-specific risks that may not be captured through formal mechanisms.

An integrated approach to risk mitigation requires coordination across administrative levels and alignment between policy guidelines and ground-level practices. It also necessitates continuous feedback loops, where information from monitoring and evaluation processes informs improvements in risk management strategies.

From an analytical perspective, the presence of uncertainty and variability in risk occurrence highlights the limitations of deterministic evaluation models. A neutrosophic framework can enhance risk assessment by explicitly incorporating degrees of certainty, uncertainty, and non-compliance in evaluating different risk factors. This allows for a more nuanced understanding of risk conditions and supports more informed decision-making.

Overall, effective risk identification and mitigation are essential for ensuring the safety, reliability, and sustainability of the Mid-Day Meal Scheme. By adopting a proactive, integrated, and uncertainty-aware approach, the program can better safeguard beneficiary health while maintaining operational efficiency and public confidence.

9.4 Neutrosophic Evaluation of Quality Uncertainty

Traditional approaches to food quality assessment often assume that compliance can be measured with certainty. However, in practice, evaluations are frequently affected by incomplete data, inconsistent reporting, and context-specific variations.

Neutrosophic logic provides a more comprehensive framework by incorporating three independent components:

- **Truth (T):** The extent to which quality standards are satisfied.

- **Indeterminacy (I):** The degree of uncertainty arising from incomplete or ambiguous information.

- **Falsity (F):** The extent of deviation from prescribed standards.

This framework allows evaluators to move beyond binary or averaged assessments and explicitly represent uncertainty in quality evaluation.

9.4.1 Application to Food Quality Assessment

Neutrosophic evaluation can be applied to various aspects of the scheme, including ingredient quality, hygiene practices, and meal delivery processes. Each component can be assessed independently, allowing for a more nuanced representation of performance.

9.4.2 Benefits of Neutrosophic Evaluation

The neutrosophic approach offers several advantages:

- It captures uncertainty and variability inherent in large-scale programs.
- It distinguishes between incomplete information and actual non-compliance.
- It enhances decision-making by identifying areas requiring targeted intervention.

9.5 Summary

Ensuring food quality, hygiene, and safety in the Mid-Day Meal Scheme requires coordinated efforts across multiple levels of implementation. While monitoring and risk management systems provide essential safeguards, their effectiveness is influenced by contextual variability and operational challenges.

By integrating neutrosophic evaluation techniques, policymakers can better account for uncertainty and complexity in assessing program performance. This approach enables a more realistic and transparent evaluation, ultimately contributing to improved health outcomes, enhanced program credibility, and greater community trust.

Chapter 10

Human Resource and Stakeholder Management

The effective implementation of the Mid-Day Meal Scheme extends beyond financial provisions and policy directives; it fundamentally depends on the efficient management of human resources and the coordinated participation of diverse stakeholders. As a large-scale and decentralized welfare program, the scheme relies on the collective efforts of individuals operating at different levels of administration, each contributing to the planning, preparation, supervision, and delivery of meals.

Human resource and stakeholder management in this context is inherently multidimensional, involving not only the allocation of responsibilities but also the development of skills, motivation, accountability, and collaboration among actors. The interaction between these elements determines the operational efficiency, quality of service delivery, and overall impact of the scheme. Furthermore, variability in human performance, institutional capacity, and stakeholder engagement introduces uncertainty, making it essential to adopt flexible and context-sensitive management approaches.

10.1 Role of Cooks, Helpers, Teachers, and Administrators

The Mid-Day Meal Scheme operates through a network of actors whose roles are interdependent and complementary. The effectiveness of the program depends on the clarity of these roles, their coordination, and the consistency with which responsibilities are fulfilled.

10.1.1 Cooks and Helpers

Cooks and helpers constitute the frontline workforce responsible for the direct execution of meal preparation and delivery. Their role is central to ensuring that the scheme meets its nutritional and safety objectives. Beyond basic cooking activities, their responsibilities include maintaining hygiene standards, managing raw materials, and ensuring timely meal distribution.

The performance of cooks and helpers is influenced by factors such as training, working conditions, availability of infrastructure, and workload. In many cases, they operate under resource constraints and limited institutional support, which may affect the consistency

and quality of meal preparation. Therefore, their role must be understood not merely as operational but as a critical determinant of program outcomes.

10.1.2 Teachers

Teachers play a dual and often complex role within the scheme, balancing their primary educational responsibilities with supervisory functions related to meal provision. Their involvement includes monitoring food quality, ensuring equitable distribution, and maintaining discipline during meal times.

In addition, teachers contribute to the broader objectives of the scheme by promoting nutritional awareness and healthy eating practices among students. Their position as trusted authority figures enables them to influence student behavior and reinforce the educational dimension of the program.

However, the additional responsibilities associated with the scheme may place an administrative burden on teachers, potentially affecting classroom activities. This dual role requires careful management to ensure that both educational and supervisory functions are effectively balanced.

10.1.3 Administrators

Administrators, including school heads, district officials, and state-level authorities, are responsible for the overall planning, coordination, and governance of the scheme. Their functions include managing procurement systems, ensuring timely fund allocation, monitoring implementation, and enforcing compliance with policy guidelines.

Administrative effectiveness is a key determinant of program success, as it influences resource availability, operational efficiency, and accountability mechanisms. Variations in administrative capacity across regions can lead to disparities in implementation quality, highlighting the importance of strong institutional frameworks and coordination mechanisms.

10.2 Training and Capacity Building

Training and capacity building are essential components of human resource management, ensuring that stakeholders possess the knowledge and skills required to perform their roles effectively. Given the diverse nature of responsibilities within the scheme, training programs must be tailored to the specific needs of different stakeholder groups.

10.2.1 Skill Development for Cooks and Helpers

Training for cooks and helpers focuses on enhancing their technical and operational capabilities. This includes knowledge of nutritional requirements, safe food handling practices, hygiene standards, and efficient resource management. Regular training sessions can improve consistency in meal preparation and reduce the likelihood of errors or contamination.

10.2.2 Teacher Orientation

Teacher training programs aim to strengthen their capacity to perform supervisory and educational roles within the scheme. This includes developing skills in monitoring, reporting, and addressing issues related to meal quality and student participation. Orientation programs also emphasize the broader social and nutritional objectives of the scheme, encouraging teachers to integrate these aspects into their educational activities.

10.2.3 Administrative Training

Administrative training focuses on improving managerial and analytical capabilities. This includes project management, financial planning, data analysis, and the use of digital tools for monitoring and reporting. Training in advanced evaluation methods, including neutrosophic approaches, can further enhance the ability of administrators to manage uncertainty and make informed decisions.

Overall, capacity building is not a one-time activity but a continuous process that must adapt to changing program requirements and contextual challenges.

10.3 Motivation and Welfare of Staff

The effectiveness of human resources is closely linked to their level of motivation, job satisfaction, and overall well-being. In the context of the Mid-Day Meal Scheme, where many workers operate under challenging conditions, attention to staff welfare is essential for sustaining performance and ensuring quality outcomes.

Financial incentives, including timely payment of wages and performance-based rewards, play a crucial role in motivating staff. However, non-financial factors such as recognition, job security, and a supportive work environment are equally important. Ensuring safe working conditions, providing adequate infrastructure, and minimizing occupational hazards contribute to both efficiency and morale.

Opportunities for skill development and career progression can further enhance motivation by creating a sense of professional growth and long-term engagement. Recognition of exemplary performance, whether through formal awards or informal appreciation, fosters a positive work culture and encourages accountability.

10.4 Community Participation and Stakeholder Coordination

The success of the Mid-Day Meal Scheme is not solely dependent on internal administrative mechanisms but also on the active participation of external stakeholders, including parents, community members, and local organizations. Community involvement enhances transparency, accountability, and responsiveness, thereby strengthening the overall effectiveness of the program.

10.4.1 Parent and Community Engagement

Parents and community members play an important role in monitoring and supporting the implementation of the scheme. Their participation in School Management Commit-

tees (SMCs) provides a platform for oversight, feedback, and collective decision-making. Community engagement also helps in identifying context-specific issues and ensuring that the program remains responsive to local needs.

10.4.2 Coordination Among Stakeholders

Effective coordination among stakeholders is essential for the smooth functioning of the scheme. This includes alignment between different levels of government, collaboration with non-governmental organizations, and partnerships with local suppliers. Each stakeholder contributes specific expertise and resources, and their coordinated efforts ensure the continuity and quality of service delivery.

10.4.3 Building Social Ownership

Active stakeholder participation fosters a sense of shared responsibility and social ownership of the scheme. This not only enhances accountability but also strengthens public trust and acceptance. When communities perceive the program as their own, they are more likely to support its objectives and contribute to its sustainability.

10.5 Summary

Human resource effectiveness and stakeholder coordination are central to the successful implementation of the Mid-Day Meal Scheme. The interplay between roles, training, motivation, and community engagement determines the quality and consistency of service delivery.

Given the variability and uncertainty inherent in human performance and stakeholder interactions, traditional evaluation approaches may not fully capture the complexities involved. Neutrosophic assessment frameworks provide a valuable tool for addressing this challenge by incorporating degrees of certainty, uncertainty, and inconsistency in evaluating human resource performance.

By adopting a comprehensive and adaptive approach to human resource and stakeholder management, the Mid-Day Meal Scheme can enhance its operational efficiency, improve service quality, and achieve its broader objectives of nutritional security, educational support, and social inclusion.

Chapter 11

Performance Evaluation and Managerial Effectiveness

Evaluating the performance of the Mid-Day Meal Scheme is a multidimensional and dynamic process that extends beyond the measurement of outputs to include the assessment of efficiency, effectiveness, equity, and managerial responsiveness. In large-scale social welfare programs, performance evaluation serves not only as a diagnostic tool but also as a strategic mechanism for guiding policy decisions, improving operational practices, and enhancing accountability.

Given the scale, diversity, and complexity of the Mid-Day Meal Scheme, performance cannot be assessed through a single indicator or deterministic framework. Instead, it requires a comprehensive approach that integrates quantitative metrics, qualitative insights, and uncertainty-aware analytical models. Variations in implementation contexts, data inconsistencies, and the presence of conflicting evidence further necessitate the use of advanced evaluation techniques capable of capturing ambiguity and partial information.

This chapter presents a structured framework for performance evaluation, encompassing key performance indicators (KPIs), multidimensional assessment of efficiency, effectiveness, and equity, and the application of neutrosophic decision matrices for ranking and comparative analysis.

11.1 Key Performance Indicators (KPIs)

The selection of appropriate KPIs is fundamental to any evaluation framework, as it determines the scope and depth of analysis. In the context of the Mid-Day Meal Scheme, KPIs must capture not only operational outputs but also qualitative dimensions and social impacts.

- **Coverage:** Reflects the extent to which eligible beneficiaries receive meals consistently, indicating the reach and inclusiveness of the program.
- **Nutritional Adequacy:** Measures compliance with prescribed dietary standards, including caloric value, protein content, and micronutrient availability. This indicator directly relates to the core objective of improving child nutrition.
- **Meal Quality:** Encompasses taste, hygiene, presentation, and acceptability, influencing consumption behavior and program effectiveness.

- **Timeliness:** Evaluates the consistency and punctuality of meal delivery, which affects both student participation and operational efficiency.
- **Attendance Impact:** Assesses the scheme's influence on school attendance, retention rates, and overall student engagement.
- **Cost Efficiency:** Examines the relationship between financial inputs and nutritional outputs, reflecting the optimal utilization of resources.
- **Administrative Efficiency:** Captures the effectiveness of procurement systems, record-keeping, fund management, and coordination mechanisms.
- **Equity Measures:** Evaluates the fairness of benefit distribution across socio-economic groups, genders, and regions.

These KPIs collectively provide a holistic view of program performance, enabling evaluators to balance operational, nutritional, and social dimensions.

11.2 Measurement of Efficiency, Effectiveness, and Equity

A comprehensive evaluation requires the simultaneous consideration of efficiency, effectiveness, and equity, as these dimensions capture different but interrelated aspects of performance.

11.2.1 Efficiency

Efficiency refers to the optimal utilization of resources to achieve desired outputs. In the context of the Mid-Day Meal Scheme, efficiency is not limited to cost minimization but includes the effective management of time, labor, and materials.

- Cost per meal relative to nutritional value delivered.
- Efficiency of supply chain and inventory management systems.
- Reduction of food wastage through improved planning and monitoring.
- Utilization of human resources and adherence to operational schedules.

However, efficiency must be interpreted cautiously, as excessive focus on cost reduction may compromise quality and equity objectives.

11.2.2 Effectiveness

Effectiveness evaluates the extent to which the scheme achieves its intended objectives. This includes both direct and indirect outcomes:

- Improvement in nutritional status and health indicators among beneficiaries.
- Enhanced school attendance, retention, and participation.

- Compliance with food safety, hygiene, and quality standards.
- Contribution to broader educational and social outcomes.

Effectiveness is inherently context-dependent and may vary across regions due to differences in implementation quality and socio-economic conditions.

11.2.3 Equity

Equity focuses on the fairness and inclusiveness of program benefits. It ensures that the scheme reaches marginalized and vulnerable populations without discrimination.

- Regional disparities in coverage and quality.
- Gender-based differences in participation and access.
- Inclusion of socially and economically disadvantaged groups.

Balancing efficiency, effectiveness, and equity is a central challenge, as improvements in one dimension may not always align with the others.

11.3 Neutrosophic Decision Matrices for Performance Ranking

Traditional evaluation approaches often assume precise and consistent data, which is rarely the case in large-scale social programs. To address this limitation, neutrosophic logic provides a flexible framework that incorporates uncertainty and partial truth.

Each performance indicator is represented as a neutrosophic triplet:

$$\text{Performance} = (T, I, F)$$

where:

- T represents the degree of achievement.
- I captures uncertainty or indeterminacy.
- F represents the degree of non-compliance.

This representation allows evaluators to explicitly account for incomplete, inconsistent, or conflicting data.

11.3.1 Construction of Decision Matrices

A neutrosophic decision matrix is constructed with:

- Rows representing schools, districts, or regions.
- Columns representing KPIs.
- Entries as neutrosophic triplets (T, I, F).

This structure enables the integration of multiple performance dimensions within a unified analytical framework.

11.3.2 Aggregation and Ranking

Aggregation methods, such as neutrosophic weighted averaging, are used to compute overall performance scores. These methods allow:

- Incorporation of criterion weights reflecting relative importance.
- Preservation of uncertainty during aggregation.
- Generation of rankings that reflect both performance and data reliability.

Sensitivity analysis further enhances decision-making by identifying criteria that contribute most to uncertainty, guiding targeted interventions.

11.4 Comparative Analysis Across Schools and Regions

Comparative analysis is essential for identifying patterns, disparities, and best practices within the scheme. It enables policymakers to move from descriptive evaluation to actionable insights.

- **Regional Analysis:** Highlights variations in performance across states and districts, reflecting differences in administrative capacity and socio-economic conditions.
- **School-Level Analysis:** Identifies high-performing and underperforming institutions, enabling targeted support and resource allocation.
- **Temporal Analysis:** Examines trends over time to assess improvements, stagnation, or emerging challenges.
- **Visualization Techniques:** Graphical representations such as heatmaps, radar charts, and neutrosophic plots facilitate the communication of complex, uncertainty-aware insights.

Comparative evaluation not only enhances transparency but also supports knowledge sharing and continuous improvement.

11.5 Managerial Implications

The integration of neutrosophic evaluation into performance assessment has significant implications for managerial decision-making. It enables administrators to:

- Distinguish between confirmed performance gaps and areas of uncertainty.
- Prioritize interventions based on both impact and reliability of data.
- Develop adaptive strategies that respond to context-specific challenges.
- Improve accountability and transparency in reporting.

By acknowledging uncertainty rather than ignoring it, managers can make more informed and resilient decisions.

11.6 Summary

Performance evaluation and managerial effectiveness are central to the success of the Mid-Day Meal Scheme. A comprehensive evaluation framework must integrate multiple dimensions, including efficiency, effectiveness, and equity, while accounting for uncertainty and variability.

The use of neutrosophic decision matrices provides a powerful tool for achieving this objective, enabling a more realistic and nuanced assessment of program performance. Through systematic evaluation and comparative analysis, policymakers and administrators can enhance operational efficiency, improve service quality, and ensure equitable distribution of benefits, ultimately strengthening the overall impact of the scheme.

Chapter 12

Economic Dimensions of the Mid-Day Meal Scheme

The Mid-Day Meal Scheme represents one of the largest publicly funded school nutrition programs globally and constitutes a significant component of India's social sector expenditure. While the scheme's primary objectives focus on improving child nutrition, enhancing school enrollment, and promoting social inclusion, its economic implications extend far beyond these immediate outcomes. The financial, labor, and welfare effects of Mid-Day Meal Scheme are intertwined with broader developmental goals, making it a vital instrument in the design of integrated social and economic policies.

From a public finance perspective, the scheme entails substantial budgetary allocations, requiring efficient utilization of funds and cost-effective procurement, preparation, and distribution of meals. Analyses of expenditure patterns, per-student costs, and regional variation in fund utilization provide insights into the scheme's fiscal sustainability and efficiency. Furthermore, Mid-Day Meal Scheme represents a mechanism for targeted public spending that directly affects household welfare, particularly for low-income and food-insecure families. By reducing household food expenditure and supplementing daily nutrition, the scheme can alleviate short-term poverty, increase disposable income, and indirectly influence household labor supply and consumption patterns.

The economic dimensions of Mid-Day Meal Scheme also extend to labor markets and local economies. Employment generation occurs both directly, through cooks, helpers, and administrative staff, and indirectly, through the procurement of raw materials from local suppliers and small-scale food vendors. Such economic activity contributes to rural livelihoods and stimulates regional markets, creating positive multiplier effects. Moreover, the scheme's impact on human capital formation—by improving cognitive development, school attendance, and learning outcomes—has long-term implications for productivity, skill accumulation, and economic growth.

In addition, Mid-Day Meal Scheme intersects with issues of equity and social mobility. By providing meals in schools, the scheme reduces opportunity costs for parents, particularly in marginalized communities, thereby increasing school participation and future earning potential of children. This aspect highlights the role of the program not only as a welfare initiative but also as a strategic investment in human capital that can enhance intergenerational equity and reduce income disparities.

This chapter examines the economic dimensions of Mid-Day Meal Scheme by integrating insights from public finance, welfare economics, labor economics, and development studies. It explores both microeconomic effects at the household and community level,

and macroeconomic implications for public spending, labor markets, and human capital development. The analysis emphasizes the multidimensional economic significance of the scheme, situating it within the broader framework of development policy and social investment in India.

12.1 Public Expenditure and Fiscal Perspective

From a fiscal standpoint, the Mid-Day Meal Scheme represents a substantial component of India's education and social welfare budget, reflecting the state's commitment to redistributive policy aimed at improving child welfare and educational participation. The scheme is jointly financed by central and state governments, with expenditures allocated to multiple components, including the procurement of food grains, cooking costs, infrastructure development, monitoring systems, and administrative overheads. These allocations vary across states, depending on local food prices, population density, and administrative capacity, highlighting the heterogeneity of fiscal commitment at the subnational level.

While critics often raise concerns regarding budgetary efficiency, potential leakages, and the fiscal burden of Mid-Day Meal Scheme, development economics literature frames such social expenditures as strategic investments rather than mere consumption. By ensuring nutritional supplementation and improving school attendance, the scheme contributes to the formation of human capital, which has long-term implications for labor productivity and economic growth. Economies of scale in procurement, centralized distribution mechanisms, and standardized menus further enhance cost-effectiveness, although regional disparities, infrastructural constraints, and administrative inefficiencies introduce variability in actual expenditures and outcomes.

From a policy perspective, evaluating the fiscal dimension of Mid-Day Meal Scheme involves assessing not only the magnitude of expenditure but also the efficiency and equity of fund utilization. Monitoring mechanisms, audit systems, and performance-linked evaluations can help mitigate inefficiencies, ensuring that public resources generate maximum social and economic returns. The fiscal perspective thus provides a critical lens for understanding the sustainability, scalability, and long-term viability of the scheme within India's broader social sector investment framework.

12.2 Cost–Benefit Considerations

Economic evaluation of the Mid-Day Meal Scheme requires a comprehensive cost–benefit framework that captures both tangible and intangible outcomes. Direct costs include food procurement, transportation, storage, cooking, serving, and program monitoring, while indirect costs may involve training of personnel, maintenance of kitchen infrastructure, and administrative coordination. Benefits, on the other hand, extend beyond immediate nutritional supplementation to include improved school enrolment and attendance, reduced dropout rates, enhanced cognitive development, and long-term gains in health and learning capacity.

Several empirical studies indicate that the economic benefits of Mid-Day Meal Scheme particularly those associated with increased educational attainment and enhanced health outcomes often outweigh operational costs, providing a positive net return on public investment. For instance, improved school participation can lead to higher lifetime earnings,

greater labor market productivity, and reduced dependence on social welfare programs. Similarly, adequate nutrition during childhood mitigates health risks, reduces absenteeism, and lowers future healthcare expenditures, generating both private and public benefits.

However, precise quantification of costs and benefits remains challenging due to several factors. Data limitations, regional heterogeneity, inconsistent monitoring practices, and variability in meal quality introduce uncertainty in estimating both expenditures and outcomes. Furthermore, intangible benefits such as social integration, equity promotion, and empowerment of marginalized communities are difficult to monetize, yet they constitute a critical component of the scheme's overall social value. These challenges underscore the relevance of evaluation frameworks—such as neutrosophic analysis—that can accommodate partial information, conflicting evidence, and indeterminacy, thereby providing a more realistic and context-sensitive assessment of Mid-Day Meal Scheme's economic impact.

12.3 Household Welfare and Income Effects

At the household level, the Mid-Day Meal Scheme functions as an implicit income transfer, providing a direct economic benefit to families, particularly those in low-income and food-insecure households. By supplying one nutritious meal per school day, the scheme effectively reduces household expenditure on food, freeing up resources for other essential needs such as healthcare, clothing, or supplementary education. The income effect is particularly pronounced for households with multiple school-going children, where cumulative savings can significantly ease short-term consumption constraints and enhance overall welfare.

Beyond immediate financial relief, Mid-Day Meal Scheme has broader economic implications for household decision-making. Reduced opportunity costs of schooling—by mitigating the need for children to contribute to household labor or domestic chores—encourage greater educational participation. In economic terms, this represents an investment in human capital that has the potential to increase future earning capacity and intergenerational mobility. However, the welfare gains are not uniform across all households. Variations in meal quality, punctuality of provision, and regional infrastructure introduce uncertainty in the magnitude of income effects, with some households experiencing more substantial benefits than others. Such heterogeneity underscores the importance of integrating partial and indeterminate information when evaluating household-level economic impacts.

12.4 Labor Market and Employment Effects

The implementation of Mid-Day Meal Scheme generates significant employment opportunities at multiple levels of the program. Direct employment arises from hiring cooks, kitchen helpers, and administrative staff, while indirect employment is created through local procurement of raw materials and the engagement of self-help groups and small-scale food suppliers. These labor market effects contribute to increased household income, stimulate local economic activity, and support livelihoods, particularly for women and marginalized groups who constitute a large share of the workforce in school meal preparation and delivery.

Despite these positive outcomes, the labor effects of Mid-Day Meal Scheme also exhibit structural limitations. Employment is often characterized by low wages, informal contractual arrangements, and limited job security, which constrain the long-term economic stability of beneficiaries. Additionally, variations in state-level implementation and resource allocation result in uneven distribution of employment opportunities across regions. Economic assessments of Mid-Day Meal Scheme labor outcomes thus reveal a coexistence of welfare gains and systemic vulnerabilities, highlighting the need for complementary policy measures such as formalization of employment, wage standardization, and capacity-building programs to enhance the scheme's broader developmental impact.

Overall, Mid-Day Meal Scheme exemplifies the dual role of social programs in generating both household-level welfare and local economic activity. By alleviating consumption constraints and creating employment opportunities, the scheme contributes to poverty reduction and community development, while simultaneously revealing areas where targeted policy interventions are necessary to address persistent structural limitations and ensure equitable economic benefits.

12.5 Human Capital Formation and Long-Term Growth

From a development economics perspective, one of the most significant long-term economic impacts of the Mid-Day Meal Scheme lies in its contribution to human capital formation. By providing consistent nutritional support and incentivizing school attendance, the scheme enhances both physical and cognitive development among children. Improved nutrition during critical growth periods positively influences brain development, concentration, and learning capacity, while increased participation in schooling raises educational attainment, literacy, and skill acquisition. These combined effects constitute foundational elements of human capital that are crucial for future labor productivity and sustained economic growth.

Although the causal link between school feeding programs and macroeconomic growth is complex and difficult to quantify precisely, theoretical and empirical literature consistently suggests that early-life investments yield high social and economic returns. Children who benefit from improved nutrition and schooling are more likely to achieve higher lifetime earnings, participate effectively in the labor market, and contribute to societal productivity. Moreover, the long-term impact of such interventions extends beyond individual beneficiaries to society at large, generating positive externalities in terms of public health, reduced social welfare dependency, and intergenerational poverty alleviation.

The indeterminate nature of these long-term outcomes underscores the importance of evaluation approaches that explicitly recognize uncertainty. Variability in regional implementation, differences in program quality, and contextual socio-economic factors mean that not all beneficiaries experience uniform gains. By incorporating indeterminacy into the assessment, neutrosophic analysis enables a more realistic and nuanced understanding of Mid-Day Meal Scheme's contribution to human capital formation and long-term economic growth, acknowledging both confirmed benefits and areas of uncertainty.

12.6 Economic Inequality and Redistribution

The Mid-Day Meal Scheme also plays a significant redistributive role within India's socio-economic landscape. By providing a universal entitlement in public schools, the scheme

disproportionately benefits children from economically disadvantaged households, ensuring access to nutrition and educational opportunities that might otherwise be unavailable. In this sense, Mid-Day Meal Scheme functions as a targeted social investment that reduces inequality, mitigates the intergenerational transmission of poverty, and promotes greater social inclusion.

However, the redistributive effectiveness of the scheme is contingent upon consistent and equitable implementation. Variations in infrastructure, administrative efficiency, and local socio-cultural factors result in differential access to meals across regions and communities. In some areas, caste hierarchies, gender norms, or logistical constraints may limit the participation of marginalized groups, thereby diluting the intended equity-enhancing effects. Furthermore, differences in meal quality and program reliability can exacerbate disparities in nutritional and educational outcomes.

Economic analysis of Mid-Day Meal Scheme must therefore account for both the scheme's equity-promoting mechanisms and the structural barriers that limit its effectiveness. By integrating quantitative measures of participation and nutritional intake with qualitative assessments of inclusion and access, evaluators can better capture the multidimensional redistributive impact of the program. Neutrosophic evaluation, with its capacity to handle indeterminacy and conflicting evidence, is particularly well-suited for analyzing these equity dimensions, providing policymakers with actionable insights to strengthen inclusion and enhance the scheme's redistributive potential.

12.7 Economic Evaluation under Uncertainty

Traditional economic evaluation methods typically rely on deterministic assumptions, precise cost–benefit estimates, and stable implementation environments. While such methods are useful in controlled contexts, they often fail to capture the complexities inherent in large-scale social welfare programs like the Mid-Day Meal Scheme. In practice, uncertainties abound, including variability in program implementation across regions, inconsistencies in data reporting, differences in meal quality, and unpredictable long-term effects on education, health, and labor market outcomes. These uncertainties undermine the reliability of conventional economic models and highlight the need for alternative frameworks capable of accommodating partial knowledge and indeterminate information.

Integrating economic evaluation with a neutrosophic framework addresses these challenges by explicitly representing three independent components of assessment: truth (T), indeterminacy (I), and falsity (F). This approach enables the synthesis of quantitative data (e.g., expenditure, enrollment, nutritional intake) with qualitative insights from field observations and expert judgments, while also capturing contradictory or incomplete evidence. For example, reported improvements in school attendance may coexist with field observations of irregular meal delivery, generating indeterminacy that classical cost–benefit analyses would ignore or misrepresent. By acknowledging and modeling such uncertainty, neutrosophic economic evaluation provides a more realistic and policy-relevant picture of Mid-Day Meal Scheme's impact, allowing stakeholders to make informed decisions despite incomplete or conflicting information.

Moreover, the neutrosophic approach facilitates sensitivity and robustness analyses of economic outcomes, highlighting which program attributes most strongly influence fiscal efficiency, household welfare, and human capital returns. It allows policymakers to identify critical leverage points where interventions—such as strengthening procurement

processes, improving kitchen infrastructure, or enhancing monitoring systems—can reduce uncertainty and maximize the social and economic benefits of the scheme. This perspective emphasizes that economic evaluation in complex social programs must move beyond rigid deterministic models to frameworks capable of handling ambiguity and partial knowledge.

12.8 Policy Implications from an Economic Perspective

From an economic policy standpoint, the findings underscore that the Mid-Day Meal Scheme should be regarded not merely as a fiscal expenditure but as a strategic investment in human capital, social equity, and long-term economic growth. Recognizing the economic value of improved child nutrition, increased school participation, and enhanced cognitive development positions Mid-Day Meal Scheme as a high-return social investment that can generate substantial public and private benefits over time. However, the realization of these returns depends on the quality and reliability of program implementation, the efficiency of resource allocation, and the ability to adapt to local socio-economic contexts.

Policy recommendations emerging from this analysis emphasize the need to strengthen governance mechanisms, improve monitoring and evaluation systems, and reduce indeterminacy in key program areas. For instance, consistent data collection, timely fund disbursement, and standardized quality control measures can enhance the predictability and effectiveness of Mid-Day Meal Scheme, thereby increasing economic returns. Additionally, adaptive policy design that accounts for regional variation and local constraints can mitigate uncertainty while ensuring equitable distribution of benefits.

Ultimately, uncertainty-aware evaluation frameworks, such as the neutrosophic approach, provide policymakers with actionable insights to balance fiscal responsibility with social investment objectives. By explicitly incorporating indeterminacy and conflicting evidence, these frameworks enhance the transparency, robustness, and credibility of economic assessments, supporting informed decisions about budget allocation, program expansion, and complementary interventions. The economic sustainability and long-term impact of Mid-Day Meal Scheme therefore depend not only on budgetary commitment but also on institutional capacity, adaptive governance, and continuous learning from evaluative evidence.

Chapter 13

Policy Implications under Neutrosophic Findings

The neutrosophic evaluation of the Mid-Day Meal Scheme provides a nuanced understanding of program performance by explicitly capturing degrees of truth, indeterminacy, and falsity across multiple evaluation attributes. Unlike conventional assessment frameworks that often rely on deterministic or purely statistical measures, neutrosophic analysis reveals areas of uncertainty, contradictory evidence, and partial knowledge, highlighting dimensions of performance that might otherwise be overlooked. These insights carry important implications for policy design, implementation, and monitoring, particularly in large-scale social welfare programs characterized by administrative complexity, socio-cultural variability, and resource constraints.

By identifying attributes with high indeterminacy—such as meal quality, regional implementation efficiency, and stakeholder perceptions—the neutrosophic assessment signals areas where additional attention, capacity-building, or data collection is required. For example, variability in kitchen infrastructure, supply chain reliability, and administrative coordination may not be fully captured by conventional performance metrics, yet they significantly affect program outcomes. Recognizing such uncertainties allows policymakers to prioritize interventions in a targeted and evidence-informed manner, thereby improving both the effectiveness and efficiency of Mid-Day Meal Scheme.

Furthermore, neutrosophic findings support adaptive and context-sensitive decision-making. Policy measures can be tailored to regional and local conditions, accounting for heterogeneity in socio-economic contexts, governance capacity, and beneficiary needs. For instance, states or districts exhibiting high indeterminacy in attendance impact or nutritional adequacy may benefit from enhanced monitoring systems, supplementary training for personnel, or community engagement initiatives to strengthen program participation. Conversely, regions with relatively high certainty and positive performance can serve as models for best practices, enabling knowledge transfer and scaling of effective strategies.

Finally, the integration of neutrosophic insights into policy design encourages transparency and reflexivity. By explicitly acknowledging uncertainty and conflicting evidence, policymakers can communicate program limitations and potential risks more effectively to stakeholders, build consensus around adaptive interventions, and foster a culture of continuous learning. In sum, neutrosophic evaluation not only enhances the analytical rigor of social program assessment but also provides actionable guidance for designing, implementing, and refining policies that are resilient, equitable, and responsive to the complex realities of large-scale welfare initiatives such as Mid-Day Meal Scheme.

13.1 Decision-Making under Uncertainty

Conventional policy decisions often rely on deterministic indicators, assuming stable program implementation, complete data, and unambiguous outcomes. In the context of the Mid-Day Meal Scheme, however, performance varies across multiple dimensions, and available evidence is frequently partial, inconsistent, or contradictory. The neutrosophic evaluation explicitly captures this complexity by representing outcomes in terms of truth (T), indeterminacy (I), and falsity (F), allowing policymakers to move beyond simplistic binary classifications of success or failure.

Understanding the degrees of indeterminacy is particularly valuable for decision-making under uncertainty. For instance, certain districts may show strong enrolment outcomes (high T) but ambiguous nutritional adequacy (high I), while other areas may exhibit conflicting evidence between administrative records and field observations. By systematically quantifying these dimensions, neutrosophic analysis enables policymakers to identify regions, attributes, or processes where further investigation, monitoring, or targeted intervention is needed, rather than treating all gaps uniformly.

Decision-making informed by neutrosophic findings emphasizes risk-awareness, flexibility, and adaptive planning. Policies can be designed to prioritize high-indeterminacy areas, allocate resources dynamically, and implement pilot interventions that are continuously evaluated and adjusted based on emerging evidence. This approach also supports contingency planning, as decision-makers can explicitly account for uncertainty in expected outcomes, thereby reducing the likelihood of unintended consequences and inefficient resource allocation.

Moreover, neutrosophic analysis facilitates communication of uncertainty to stakeholders, including local administrators, community groups, and funding agencies. By transparently presenting the coexistence of positive, negative, and indeterminate evidence, policymakers can foster informed dialogue, encourage participatory problem-solving, and build consensus around targeted solutions. In essence, decision-making under uncertainty, guided by neutrosophic insights, transforms evaluation from a static judgment into a dynamic, context-sensitive, and evidence-driven policy process.

13.2 Region-Specific Policy Insights

The neutrosophic case study analysis of the Mid-Day Meal Scheme highlights substantial regional variability in program performance. While certain states or districts demonstrate high truth values (T) for attributes such as nutritional adequacy, enrolment, and attendance, other regions exhibit elevated indeterminacy (I) or falsity (F), reflecting inconsistent implementation, gaps in monitoring, or conflicting evidence from administrative records and field observations. These variations underscore the importance of context-sensitive policy approaches that account for local socio-economic, cultural, and infrastructural factors.

Neutrosophic assessment provides a structured framework to differentiate between true underperformance and areas of uncertainty. For example, a district with high falsity values for meal quality clearly signals implementation deficiencies that require corrective interventions, such as infrastructure improvements, training for kitchen staff, or stricter adherence to nutritional norms. Conversely, a region with high indeterminacy but moderate truth values may not suffer from outright failure but instead indicates areas where data quality, reporting mechanisms, or stakeholder perceptions are inconsistent. In such

cases, targeted capacity building, enhanced monitoring, or pilot initiatives can reduce uncertainty and improve overall program effectiveness without prematurely labeling the region as underperforming.

Region-specific insights also facilitate more efficient resource allocation. By identifying which attributes and locations are characterized by uncertainty versus confirmed shortcomings, policymakers can prioritize interventions that maximize impact while minimizing waste. For instance, resources can be directed toward improving supply chain management and local administrative capacity in high-indeterminacy regions, while regions exhibiting clear performance gaps may receive technical support, auditing, or policy reinforcement.

Furthermore, these insights support adaptive and participatory policy design. Local governments, school administrators, and community organizations can use neutrosophic findings to identify context-specific challenges, co-develop solutions, and monitor incremental improvements. By explicitly incorporating regional heterogeneity and uncertainty, neutrosophic evaluation transforms the policy discourse from a one-size-fits-all approach to a nuanced, data-informed, and locally responsive strategy, enhancing both equity and effectiveness of the Mid-Day Meal Scheme.

13.3 Reducing Indeterminacy through Governance

High levels of indeterminacy in the evaluation of the Mid-Day Meal Scheme frequently reflect governance-related challenges, including weak monitoring systems, fragmented and inconsistent data collection, lack of standardized reporting protocols, and limited accountability at local and regional levels. Such governance deficiencies contribute to uncertainty in both implementation outcomes and evaluative assessments. The neutrosophic findings indicate that addressing these sources of indeterminacy should be considered a central policy objective, alongside improving conventional performance indicators such as nutritional adequacy, attendance, and social inclusion.

Strengthening administrative processes can substantially reduce indeterminacy. This may involve implementing uniform reporting templates, digitizing record-keeping, and establishing real-time monitoring dashboards that track meal preparation, distribution, and consumption. Capacity-building initiatives for school administrators, local authorities, and community-level stakeholders can further enhance operational reliability and reduce variability in program delivery. Transparency measures, such as public disclosure of performance data and participatory audits, can also mitigate ambiguity by allowing external stakeholders to verify outcomes and flag inconsistencies.

By targeting governance structures that contribute to indeterminacy, policymakers can achieve dual benefits: improving the quality and consistency of implementation, and enhancing the reliability and interpretability of program evaluations. The neutrosophic framework provides a systematic tool to identify which governance elements most strongly influence uncertainty, enabling evidence-informed interventions that are both targeted and scalable.

13.4 Practical Utility of Neutrosophic Assessment

The practical utility of neutrosophic assessment lies in its ability to integrate heterogeneous data sources, subjective expert judgments, and uncertain or conflicting evidence

into a coherent and analytically robust framework. Unlike classical binary or purely fuzzy evaluation methods, neutrosophic analysis explicitly models indeterminacy, allowing evaluators and policymakers to distinguish between confirmed successes, observed shortcomings, and areas of ambiguity. This multi-dimensional representation provides a more realistic and nuanced picture of program performance, particularly for large-scale social welfare initiatives operating under complex and variable conditions.

For policymakers, neutrosophic assessment supports informed decision-making by highlighting strengths, weaknesses, and ambiguous zones simultaneously. It facilitates prioritization of interventions, enabling targeted resource allocation to regions or attributes characterized by high uncertainty, while reinforcing best practices in areas with confirmed positive outcomes. Additionally, neutrosophic evaluation encourages adaptive policy design: by continuously updating truth, indeterminacy, and falsity components based on new data, administrators can iteratively refine strategies and respond to evolving program challenges.

The approach's adaptability extends beyond the Mid-Day Meal Scheme, making it suitable for other large-scale social welfare programs, such as conditional cash transfers, public health initiatives, and rural employment schemes, which also operate under conditions of uncertainty, conflicting evidence, and diverse stakeholder perspectives. By providing a transparent, structured, and uncertainty-aware analytical framework, neutrosophic assessment enhances the credibility, relevance, and practical utility of policy evaluation in complex real-world contexts.

Chapter 14

Conclusion and Future Scope

This chapter concludes the study by synthesizing the key findings from the neutrosophic assessment of India's Mid-Day Meal Scheme, reflecting on theoretical and methodological contributions, acknowledging inherent limitations, and proposing directions for future research. The analysis demonstrates the practical and conceptual value of neutrosophic logic in evaluating large-scale social welfare programs that operate under uncertainty, conflicting evidence, and contextual heterogeneity. By explicitly incorporating degrees of truth, indeterminacy, and falsity, the study provides a richer, more nuanced understanding of Mid-Day Meal Scheme performance than traditional evaluation approaches.

The findings indicate that while the Mid-Day Meal Scheme achieves measurable success in areas such as school enrolment, attendance, and basic nutritional outcomes, significant indeterminacy persists in attributes such as meal quality, regional implementation efficiency, and stakeholder perceptions. The neutrosophic framework enables the identification of high-indeterminacy zones, highlighting areas where additional monitoring, capacity building, and context-sensitive interventions are necessary. By distinguishing between confirmed successes, observed shortcomings, and uncertain outcomes, the study offers actionable insights for policymakers and program administrators seeking to improve both implementation and evaluation.

From a theoretical standpoint, this research demonstrates that neutrosophic logic provides a robust extension of classical, fuzzy, and intuitionistic evaluation frameworks. It bridges gaps in handling incomplete, ambiguous, and contradictory information, thereby advancing knowledge on the application of uncertainty-aware methodologies in social policy analysis. Methodologically, the study illustrates the integration of quantitative indicators, qualitative judgments, and expert opinions within a structured neutrosophic assessment process, including the construction of attribute-wise vectors, performance matrices, aggregation operators, and sensitivity analysis.

At the same time, the study acknowledges several limitations. The case study approach, while enabling in-depth contextual analysis, restricts the generalizability of findings to other regions or programs. Data availability, stakeholder subjectivity, and the inherent challenges of quantifying long-term outcomes introduce additional layers of uncertainty that are only partially addressed through neutrosophic modeling. Despite these constraints, the framework provides a systematic and transparent means to account for uncertainty, which can be adapted and extended in future research.

Future research directions include the application of neutrosophic evaluation to other social welfare programs such as conditional cash transfers, public health interventions, and rural employment schemes. Comparative studies across regions and program types

can further test the robustness and adaptability of neutrosophic methodologies. Additionally, methodological enhancements, such as the integration of interval-valued neutrosophic sets, dynamic updating of (T, I, F) values, and coupling with advanced statistical or machine learning techniques, can refine the precision and predictive power of such assessments. By combining conceptual rigor with practical applicability, future studies can expand the role of neutrosophic logic as a mainstream tool for policy evaluation in uncertain and complex social environments.

14.1 Summary of Key Findings

The neutrosophic case study analysis of the Mid-Day Meal Scheme highlights the limitations of traditional deterministic and statistical evaluation methods in capturing the multifaceted and context-dependent nature of large-scale social welfare programs. By explicitly incorporating truth (T), indeterminacy (I), and falsity (F), the study provides a comprehensive understanding of both observed outcomes and underlying uncertainties.

Key findings indicate that the scheme has achieved measurable success in critical areas such as school enrolment, attendance, and basic nutritional supplementation. These positive outcomes are reflected in relatively high truth values for the corresponding evaluation attributes, confirming the scheme's effectiveness in improving educational participation and mitigating short-term hunger among children, particularly from socio-economically disadvantaged backgrounds.

However, substantial indeterminacy persists across several other attributes, including food quality and hygiene, administrative efficiency, and social equity. These high-indeterminacy zones reveal inconsistencies between administrative records, field observations, and stakeholder perceptions. For instance, while official data may indicate compliance with nutritional standards, variations in meal preparation, portion sizes, and local food preferences introduce uncertainty that is captured in the neutrosophic framework. Similarly, administrative challenges such as delayed fund disbursement, uneven workforce allocation, and infrastructural constraints contribute to conflicting evidence regarding program efficiency.

The identification of these zones of uncertainty underscores the importance of accounting for contradictory evidence and incomplete information, which conventional evaluation approaches often overlook or suppress. The neutrosophic performance matrix and overall neutrosophic index offer a multidimensional representation of scheme performance, balancing positive outcomes, observed shortcomings, and areas of indeterminacy. This nuanced interpretation enables policymakers, program administrators, and researchers to distinguish between confirmed successes, uncertain effects, and potential failures, thereby informing targeted interventions, resource allocation, and adaptive policy design.

Overall, the study demonstrates that neutrosophic assessment not only enriches the understanding of Mid-Day Meal Scheme performance but also provides a transparent and structured methodology for evaluating complex social programs under conditions of ambiguity, variability, and partial knowledge.

14.2 Theoretical Contributions

This study makes several significant theoretical contributions to the literature on social policy evaluation and uncertainty modeling. First, it extends the application of neutro-

sophic logic to the domain of public policy, demonstrating how the triadic framework of truth (T), indeterminacy (I), and falsity (F) can be applied to complex, large-scale social welfare programs such as the Mid-Day Meal Scheme. Unlike classical, probabilistic, or fuzzy approaches, neutrosophic logic explicitly captures the coexistence of positive, negative, and uncertain evidence, offering a more expressive and realistic framework for representing policy performance.

Second, the research advances conceptual understanding of uncertainty in social policy analysis by differentiating between vagueness, randomness, and indeterminacy. While vagueness may reflect imprecise definitions and randomness captures probabilistic variability, indeterminacy arises from incomplete, contradictory, or context-dependent information—common characteristics of real-world program implementation. By formally incorporating indeterminacy as a distinct analytical component, the study enriches theoretical discussions on evaluation under uncertainty and provides a foundation for developing more nuanced models of policy effectiveness.

Third, the study contributes to the theory of multidimensional evaluation by demonstrating how neutrosophic logic accommodates heterogeneous data sources, including quantitative metrics, qualitative observations, and expert judgments. This theoretical insight underscores the relevance of neutrosophic logic not only as a mathematical construct but also as a conceptual tool for understanding the complexity, ambiguity, and contextual sensitivity inherent in social programs.

14.3 Methodological Contributions

Methodologically, the research proposes a systematic and replicable neutrosophic evaluation framework tailored to large-scale social welfare interventions. The framework integrates diverse data types—administrative records, field observations, expert opinions, and qualitative judgments—into a unified neutrosophic environment, thereby providing a structured approach for handling uncertainty, inconsistency, and indeterminacy.

Key methodological innovations include the development of neutrosophic scales for translating linguistic and subjective assessments into (T, I, F) values, the construction of attribute-wise neutrosophic vectors, and the formation of a comprehensive neutrosophic performance matrix. The study further introduces aggregation operators and overall neutrosophic indices to synthesize multi-attribute assessments, while sensitivity analysis procedures evaluate the robustness of findings under varying levels of indeterminacy.

These methodological tools collectively demonstrate the practical feasibility and adaptability of neutrosophic evaluation for complex social programs. The framework can be extended to other public sector interventions—such as health initiatives, conditional cash transfer schemes, and rural employment programs—where uncertainty, conflicting evidence, and heterogeneous stakeholder perspectives are prevalent. By providing both analytical rigor and operational flexibility, the study establishes a replicable methodology that bridges the gap between theoretical modeling and real-world policy assessment.

14.4 Limitations of the Study

Despite its theoretical and methodological contributions, this study has several limitations that should be acknowledged. First, the analysis is based on a single case study, focusing on a specific geographic and administrative context. While this approach enables in-depth

examination of contextual factors, it inherently limits the generalizability of findings to other regions or states with different socio-economic, cultural, or governance conditions.

Second, the assignment of neutrosophic values relies partially on expert judgment and subjective evaluations. Although structured elicitation procedures and aggregation operators were employed to enhance reliability, some degree of subjectivity remains unavoidable. Divergent perceptions among experts and variability in local implementation may introduce bias or influence the assessment of indeterminacy.

Third, the study does not incorporate longitudinal data to capture temporal dynamics in scheme performance. As a result, insights into the evolution of truth, falsity, and indeterminacy over time are limited. Furthermore, certain data constraints—such as incomplete administrative records, regional disparities in reporting quality, and limited information on long-term health and educational outcomes—introduce additional layers of uncertainty that are only partially addressed through the neutrosophic framework.

Finally, while neutrosophic evaluation provides a robust mechanism for handling uncertainty, it is still a relatively novel methodological approach. The selection of aggregation operators, weighting schemes, and scale definitions may influence results, requiring careful interpretation and contextual adaptation. These limitations underscore the need for cautious extrapolation and highlight opportunities for future methodological refinements.

14.5 Future Research Directions

Future research can build on the findings and framework presented in this study in several ways. One promising direction is the application of neutrosophic evaluation to multiple regions or states, enabling comparative analyses that account for socio-economic, cultural, and governance heterogeneity. Such studies could examine the variability of outcomes and indeterminacy across different administrative and demographic contexts, thereby enhancing generalizability and policy relevance.

Longitudinal research is another valuable extension, allowing scholars to explore how truth, falsity, and indeterminacy evolve over time in response to program interventions, policy reforms, and changing socio-economic conditions. This would provide dynamic insights into program effectiveness, resilience, and adaptability, which are crucial for long-term policy planning.

Methodologically, future studies may explore advanced neutrosophic models, including interval-valued neutrosophic sets, bipolar neutrosophic sets, and hybrid approaches that integrate statistical or machine learning techniques. Such enhancements can capture higher levels of uncertainty, model complex interactions among attributes, and improve predictive and evaluative precision.

Finally, expanding the application of neutrosophic assessment to other social welfare programs—such as public health initiatives, conditional cash transfers, rural employment schemes, and child development programs—offers a rich avenue for interdisciplinary research. By systematically incorporating uncertainty, conflicting evidence, and subjective perceptions, future research can further establish neutrosophic logic as a versatile and practical tool for evaluating complex public policies under real-world conditions.

Appendix A

Supplementary Neutrosophic Tables

A.1 Attribute-Wise Neutrosophic Evaluations

Table A.1: Neutrosophic Evaluation of Key Attributes of Mid-Day Meal Scheme

Attribute	**Truth** (T)	**Indeterminacy** (I)	**Falsity** (F)
Nutritional Adequacy	0.82	0.12	0.06
Enrolment and Attendance	0.78	0.15	0.07
Food Quality and Hygiene	0.65	0.25	0.10
Administrative Efficiency	0.70	0.20	0.10
Social Equity and Inclusion	0.60	0.28	0.12

A.2 Aggregated Neutrosophic Vectors

Table A.2: Aggregated Neutrosophic Vectors Across Experts

Attribute	**Aggregated** T	**Aggregated** I	**Aggregated** F
Nutritional Adequacy	0.80	0.14	0.06
Enrolment and Attendance	0.77	0.16	0.07
Food Quality and Hygiene	0.66	0.24	0.10
Administrative Efficiency	0.69	0.21	0.10
Social Equity and Inclusion	0.62	0.27	0.11

A.3 Overall Neutrosophic Index of Mid-Day Meal Scheme

Table A.3: Overall Neutrosophic Index of Mid-Day Meal Scheme

Index	$T_{overall}$	$I_{overall}$	$F_{overall}$
Mid-Day Meal Scheme Performance Index	0.71	0.20	0.09

A.4 Sensitivity Analysis: Variation in Indeterminacy

Table A.4: Effect of Increasing Indeterminacy on Overall Mid-Day Meal Scheme Index

Scenario	$T_{overall}$	$I_{overall}$	$F_{overall}$
Baseline	0.71	0.20	0.09
I + 10%	0.69	0.30	0.10
I + 20%	0.67	0.36	0.12
I + 30%	0.65	0.41	0.14

Notes:

- Truth (T), Indeterminacy (I), and Falsity (F) values range from 0 to 1.
- Aggregation was performed using weighted arithmetic mean of expert assessments.
- Sensitivity analysis demonstrates the impact of increased uncertainty (indeterminacy) on the overall neutrosophic index.

Appendix B

Expert Evaluation Questionnaire

This section presents the structured questionnaire used to collect expert evaluations for the neutrosophic assessment of the Mid-Day Meal Scheme. The questionnaire is designed to capture expert judgments on multiple attributes of the scheme, incorporating subjective perceptions, partial knowledge, and uncertainty. Experts are asked to assess each attribute using linguistic scales, which are subsequently converted into neutrosophic triplets (T, I, F).

B.1 Instructions for Experts

- Each attribute should be evaluated independently based on your knowledge, experience, and available information.
- Use the linguistic scale provided to indicate the level of performance or adequacy.
- Consider both positive evidence (truth), negative evidence (falsity), and uncertainty or ambiguity (indeterminacy) when making assessments.
- Provide brief qualitative comments to justify your evaluation for each attribute, if possible.
- All responses are confidential and used solely for research purposes.

B.2 Neutrosophic Linguistic Scale

Table B.1: Linguistic Scale for Neutrosophic Evaluation

Linguistic Assessment	**Truth** (T)	**Indeterminacy** (I)	**Falsity** (F)
Excellent / Highly Satisfactory	0.9 – 1.0	0.0 – 0.1	0.0 – 0.1
Good / Satisfactory	0.7 – 0.8	0.1 – 0.2	0.1 – 0.3
Moderate / Average	0.5 – 0.6	0.2 – 0.4	0.2 – 0.4
Poor / Unsatisfactory	0.3 – 0.4	0.3 – 0.5	0.4 – 0.6
Very Poor / Inadequate	0.0 – 0.2	0.4 – 0.6	0.7 – 1.0

B.3 Evaluation Attributes

Experts are requested to evaluate the following attributes of the Mid-Day Meal Scheme:

- **Nutritional Adequacy:** Assess whether meals meet prescribed caloric, protein, and micronutrient standards.
- **Impact on Enrolment and Attendance:** Evaluate the scheme's influence on school participation, daily attendance, and retention.
- **Food Quality and Hygiene:** Assess meal quality, safety standards, cleanliness, and acceptability among students.
- **Administrative Efficiency:** Evaluate planning, coordination, monitoring, timely fund disbursement, and supply chain management.
- **Social Equity and Inclusion:** Assess whether the scheme promotes access across caste, gender, and socio-economic groups.

B.4 Questionnaire Format

Table B.2: Sample Expert Evaluation Table

Attribute	**Truth** (T)	**Indeterminacy** (I)	**Falsity** (F)	**Comments / Observations**
Nutritional Adequacy	(,)	(,)	(,)	
Impact on Enrolment and Attendance	(,)	(,)	(,)	
Food Quality and Hygiene	(,)	(,)	(,)	
Administrative Efficiency	(,)	(,)	(,)	
Social Equity and Inclusion	(,)	(,)	(,)	

B.5 Instructions for Data Conversion

1. Convert linguistic assessments into neutrosophic triplets (T, I, F) using the predefined linguistic scale.
2. For attributes with high uncertainty or conflicting evidence, assign a higher indeterminacy (I) value.
3. Aggregate individual expert responses using neutrosophic operators to construct attribute-wise vectors and overall indices.

B.6 Notes

- Experts may provide qualitative explanations for extreme or contradictory evaluations.
- Multiple experts can be consulted to enhance reliability and reduce individual bias.
- The questionnaire is designed for adaptation to other social welfare programs beyond Mid-Day Meal Scheme.

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The Mid-Day Meal Scheme in India has been a crucial initiative aimed at enhancing child nutrition and education. This book employs neutrosophic logic to provide a detailed micro-level assessment of the program's effectiveness, challenges, and outcomes. It offers an in-depth analysis of the strengths, weaknesses, and areas for improvement of the scheme.

ISBN 978-197250206-8