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Initial Diagnosis for the Design of a Logistics Management Model to Control Food Insecurity in a Rural Area

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ABSTRACT: *Food insecurity in rural areas of Mexico represents a multifactorial challenge exacerbated by infrastructural and logistical deficiencies, beyond mere productive capacity. This paper presents the initial diagnosis and conceptual design of a Logistics Management Model aimed at controlling food insecurity—specifically in the dimensions of access and availability—in the rural area of Altamira, Tamaulipas. Methodologically, the research adopts a mixed-methods approach (qualitative and quantitative) with a descriptive, correlational, and propositional scope, integrating geospatial analysis tools (GIS) and inferential statistics. The main contribution of this study lies in the structuring of an advanced optimization model that transcends traditional logistics by incorporating Shared Corporate Social Responsibility (SCSR) strategies. This model proposes an operational synergy between the government sector, non-governmental organizations (NGOs), and socially responsible enterprises (SREs). Preliminary diagnostic results identify critical barriers in transportation, warehousing, and fragmented supply chains. In response, a management system based on the "Social Triple Helix" is proposed, designed to optimize routes, reduce distribution costs, and maximize food coverage, aligning with the National Strategic Programs (PRONACES) for food sovereignty and the Sustainable Development Goals (SDGs).*

KEYWORDS - *Advanced optimization, Altamira, food insecurity, Logistics management, rural areas, shared social responsibility*

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I. INTRODUCTION

Food security is one of the most important pillars for sustainable development and human well-being worldwide [1]. However, food insecurity persists, even with international and national interventions, and is most severely felt by vulnerable groups living in rural areas. Access to and availability of sufficient and nutritious food is a multifaceted problem shaped by economic, geographic, social, and infrastructural conditions.

In Mexico, and especially in the state of Tamaulipas, several rural and marginalized groups face significant challenges in guaranteeing their right to adequate food. This challenge is exacerbated by climate change, armed conflicts, economic crises, and disruptions in supply chains. The Food and Agriculture Organization of the United Nations [2] also reports that several million people continue to experience moderate to severe hunger or food insecurity. In the case of Mexico, as in the case of rural sectors in other countries, the situation is no different, as they must contend with additional challenges related to geographic isolation, poor infrastructure, and the practice of subsistence farming [3].

Poor logistics infrastructure in food management, from production to consumption, is a primary reason for food insecurity, leading to immense post-harvest losses, restricted market availability, and skewed food distribution.

This paper presents a study whose general objective is to conduct a diagnostic assessment to design a Logistics Management model, considering shared corporate social responsibility strategies between governmental and non-governmental organizations, to facilitate the control of food insecurity, particularly in the dimensions of access and availability, in rural areas of Altamira, Tamaulipas. This assessment is based on

infrastructure, the socioeconomic development level of the population, and other key challenges to food access, using an advanced optimization model.

An analysis of the recent dynamics of food insecurity in this area will be carried out, and a management framework will be proposed to optimize the food supply chain, infrastructure, and the specific social and economic characteristics of the population, utilizing shared corporate social responsibility programs between public and private sector organizations.

II.BACKGROUND

The body of science related to food security has advanced considerably, progressing from conceptualization to measurement and from measurement to intervention. Food insecurity is broadly described as the limited or uncertain availability of nutrient-rich food, with all the resulting impacts on health and well-being [4].

In the field of logistics and supply chain management, various models have been classified to optimize the process in diverse sectors. However, their specific usefulness in addressing food insecurity in rural environments is an area that is still not clearly understood [5]. Previous research has emphasized the role of transport and storage infrastructure for food availability [6] and the role of income and price for access to food [7].

At the regional level, there is research related to food security in Mexico, but the discrepancy between urban and rural areas is noteworthy, as evidenced by the National Council for the Evaluation of Social Development Policy (CONEVAL) [3].

The classical conception of SCSR, understood as activities peripheral to the company's core business, has become obsolete in the face of the complexity of current global challenges. In the last five years, scientific literature has shifted towards the concept of Shared Corporate Social Responsibility (SCSR) or Shared Value Creation (SVC).

This new approach posits that an organization's competitiveness and the health of the communities where it operates are mutually dependent. It is no longer about "redistributing" the value generated, but about "expanding" total economic and social value through product innovation, redefining productivity in the value chain, and building supportive clusters.

The theoretical basis of SCSR is grounded in an evolution of Freeman's Stakeholder Theory. However, recent research suggests a shift from "stakeholder management" to "collaborative governance." Responsibility does not end at the company's legal boundaries. An "extended responsibility" model has been established where anchor companies are co-responsible for the ESG (Environmental, Social, and Governance) practices of their suppliers and distributors.

SCSR implies that sustainability risks and opportunities are managed collectively. Vertical integration of ethical standards is no longer sufficient; horizontal integration of capabilities is required to raise the standard across the entire ecosystem. Recent studies [8] [9] indicate that society expects corporations to act as active political and social agents. Shared Corporate Social Responsibility demands that companies take public stances and collaborate with governments and NGOs to solve structural problems (climate change, inequality), not only to mitigate their own footprint but also to heal the system.

The contemporary theoretical framework integrates ESG criteria not as reporting metrics but as drivers of innovation. The dominant paradigm between 2022 and 2025 is the movement toward "Net Positive" companies [10]. The theory suggests that a company with Shared Corporate Social Responsibility should enrich the world more than it takes from it. This implies:

1. Environmental Regeneration: Restoring ecosystems, not just reducing emissions.

2. Radical Inclusion: Designing business models that integrate vulnerable populations into the value chain (inclusive businesses).

Industry 4.0 and 5.0 play a crucial role. Traceability through Blockchain and the use of Big Data enable radical transparency, a sine qua non for Shared Corporate Social Responsibility [11]. Current theory directly links digital transformation with a company's ability to measure and share its social impact in real time.

SCSR represents an epistemological break with Friedman's model. It concludes that, in the current context (2024-2025), a company's legitimacy to operate depends on its ability to demonstrate that its economic success is inseparable from the social and environmental progress of its surroundings. "Sharing" lies in

dissolving the boundaries between the public, private, and social spheres in pursuit of systemic common well-being.

In Tamaulipas, in particular, assessments have been conducted on the socioeconomic situation and barriers to accessing health services, but models for the operational management of processes to overcome food insecurity in marginalized rural areas appear to be underdeveloped.

This study will address the aforementioned gap by leveraging previous experience in logistics and food security, and by proposing a contextual and practical solution.

III.PROBLEM STATEMENT

Although the state of Tamaulipas boasts a large agricultural and livestock sector, a significant portion of the rural population in Altamira faces food insecurity, particularly regarding access and availability.

Initial reports and anecdotal evidence indicate that this situation is deteriorating, exacerbated by limiting infrastructure—poor roads and inadequate storage, which hinder food transportation and preservation; low socioeconomic status, which inhibits purchasing power and dietary diversity; and structural supply chain constraints (inefficient traders, high distribution costs, limited number of sales outlets), etc. These factors make it challenging for rural families to access sufficient, healthy, and good-quality food, even if such food may be relatively difficult to produce locally. This not only results in a decline in the health and well-being of communities but also perpetuates the cycle of poverty and restricts social and economic development [12].

Frequently, humanitarian assistance and government aid plans to address this problem are reactive measures or short-term solutions that fail to address the underlying issues within the rural food system. Currently, there is a significant information gap regarding how the physical interplay of factors such as storage, transportation, distribution, and inventory management contributes to food insecurity and how these can be shaped to create more resilient and equitable food systems.

The absence of an integrated and coordinated approach between the public and private sectors in the logistical management of these issues hinders effective and/or sustainable solutions. Therefore, in accordance with the above, this study aims to provide answers to the following answers to the following research problem:

What are the implications of conducting a diagnosis for the design of a logistics management model, considering infrastructure, socioeconomic level, and access to food, based on shared corporate social responsibility strategies between governmental and non-governmental entities, that can contribute to managing food insecurity (access and availability) in a rural community in Altamira, Tamaulipas; all through an advanced optimization model?

IV.METHODOLOGY

4.1. Research Approach

Inspired by [13], the study will use a mixed method integrating both qualitative and quantitative data to capture a complete view of the phenomenon, aiming to develop a robust model.

The qualitative phase will allow for an understanding of the context, challenges, and perceptions of the stakeholders involved (families, producers, merchants, authorities), including an investigation of underlying reasons and social dynamics, to also identify companies—both public and private—and corporate social responsibility programs that can be integrated as a strategic part of the model to be built.

The quantitative phase will focus on analyzing quantitative data on food insecurity indicators (e.g., food intake, distance to the market, family income), infrastructure patterns, and transportation costs for the development and implementation of the logistics model.

4.2. Type of Research

This research will be descriptive, correlational, and propositional. It is descriptive in that it defines the current state of food insecurity and logistical variables. It is correlational in that the logistical variables are correlated with food security indicators. It is propositional in that it will present an unprecedented logistics model for the problem, utilizing the corporate social responsibility of private and public industries and companies.

4.3. Research Design

An exploratory-descriptive-propositional design will be used.

- The exploratory phase will establish the primary variables and dynamics of food insecurity.

- The descriptive stage will describe the state of access and availability, infrastructure, and socioeconomic context.
- The propositional phase will conclude with the adaptation of the logistics management model through strategies from public and private organizations and CSR (Corporate Social Responsibility) programs.

4.4. Population and Sample

The study population and sample are structured as follows:

- Population: Families and households living in the rural area of the municipality of Altamira, Tamaulipas; and farmers, local retailers, and government and civil society stakeholders.
- Key Actors in the Supply Chain: Local merchants, transporters, and food distributors.
- Institutions and Organizations: Government officials from various levels of government agencies (SEGALMEX, SADER, Bienestar); NGOs working in food security, food banks, etc.
- Quantitative Sample: A representative sample of households will be selected through stratified random sampling, taking into account variables such as socioeconomic status and geographic region. The sample size will be determined appropriately to achieve statistical power.
- Qualitative Sample: Community leaders, farmers, small food vendors, health or social development officials, responsible citizens of the area, and socially responsible businesses will be recruited intentionally or through snowball sampling.

4.5. Data Collection Tools and Techniques

1. Forms (Quantitative Surveys):
    - Structured forms will be developed for:
        - Food consumption and dietary diversity.
        - Food access and purchase sites.
        - Distances and travel time to markets and supply points.
        - Family income and food expenditures.
        - Data collection on food availability and prices.
        - Access to infrastructure and basic services.
        - For certain aspects (such as food security), validated scales will be used (e.g., the Latin American and Caribbean Food Security Scale – ELCSA).
2. Semi-Structured Interviews (Qualitative):
    - Directed at key actors to obtain detailed information on:
        - Perceptions and experiences of food insecurity.
        - Logistical challenges in the domestic supply chain.
        - Perceptions of existing infrastructure and its limitations.
        - Community proposals and requirements.
        - The process of production, processing, commercialization, and consumption of food.
3. Direct Observations:
    - Field tours of the area to record infrastructure (roads, collection points, sales points, housing, health facilities); housing quality; and how food is transported.
4. Documentary Review:
    - Review of government reports, previous research, censuses, and local figures on food security, rural development, infrastructure, and socioeconomic indicators in Altamira.
5. Supply Chain Mapping:
    - Utilization of GIS (Geographic Information Systems) tools to locate distribution and storage centers, markets, and consumption areas.

V.DATA ANALYSIS

Descriptive statistics such as means, medians, standard deviations, and frequencies will be used to describe variables. Associations between intermediate variables (income, infrastructure, access to food) and with each

other, as well as with the final variable, can be tested using inferential statistics (e.g., ANOVA, regression). A statistical package (SPSS, R, or Stata) will be used.

In qualitative data: Thematic content analysis. Interview transcripts will be coded to identify patterns, problems, and/or categories.

Data synthesis: Qualitative and quantitative data will be triangulated to confirm results, improve understanding, and gain a more comprehensive view of the problems and solutions.

5.1. Steps in the Application Process of the Proposed Model

The Logistics Management Model is expected to be developed in the following stages or modules:

Step 1: Diagnosis and Mapping: This step aims to collect and analyze information on food insecurity, infrastructure, and socioeconomic conditions; as well as map the local food supply chain, actors, flows, bottlenecks, and describe the specific requirements and requests of the population.

Step 2: Design of Adapted Logistics Strategies: This step aims to study how to improve infrastructure, suggesting the rehabilitation or construction of roads, collection centers, community sales points, and storage facilities; as well as optimal transportation and distribution, allowing for the design of optimal routes, promoting accessible modes of transport, and integration into established distribution systems. Additionally, the step will study how to manage the dynamics of the process from the field to the final consumer.

Step 3: Design of Capacity and Network Improvement: This step will identify how to involve local economic development, considering that the model will support productive projects, local markets, and training for small producers and merchants; identifying and/or establishing communication channels for the population to access information on prices, availability, and support programs; this will foster interaction among small producers, consumers, local governments, and socially responsible enterprises (SREs).

Step 4: Documentation and Model Proposal: The technical documentation of the proposed model will be detailed precisely.

The following Figs. 1, 2, 3 and 4 present the specific steps of each phase of the process.

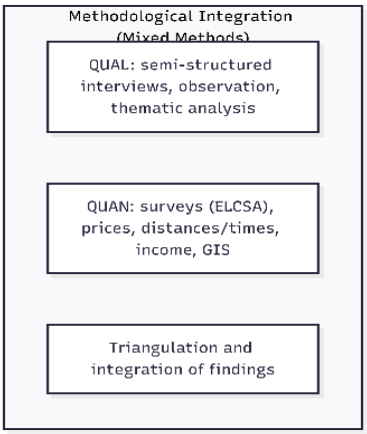
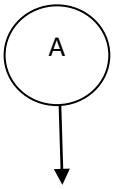


Figure 1: Methodology integration



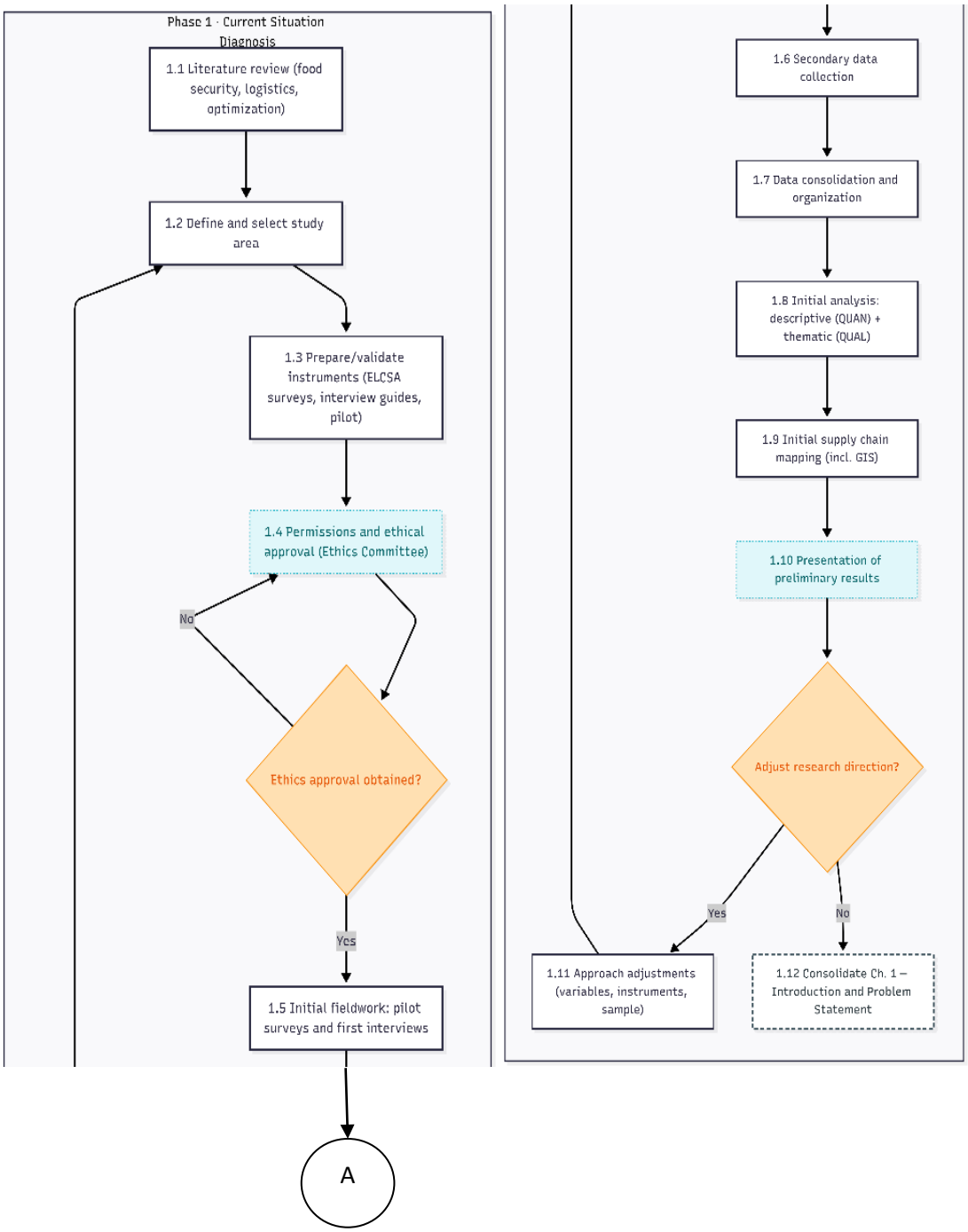


Figure 2: Phase 1 Diagram - Diagnosis and Mapping

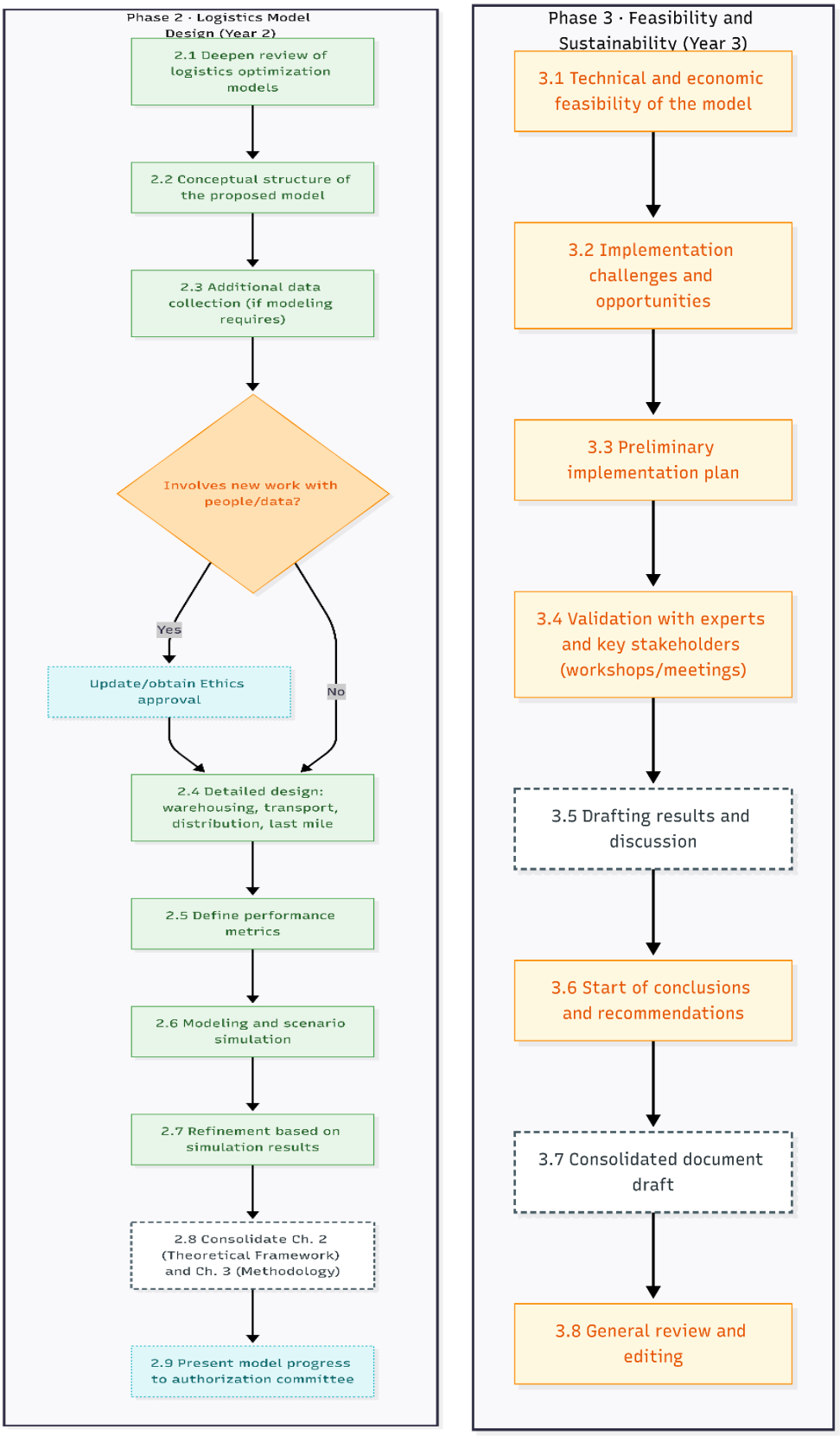


Figure 3: Phase 2 and 3 diagram - Logistics Model design and Feasibility and Sustainability

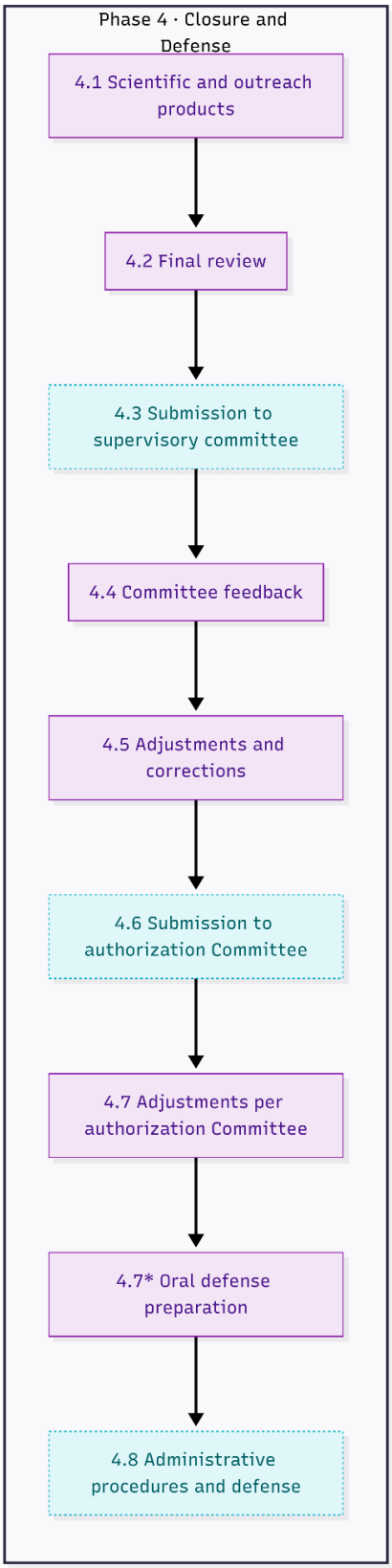


Figure 4: Phase 4 diagram – Closure and defense

VI.RESULTS

Preliminary study results confirm that food insecurity in the rural zone of Altamira is associated with poverty, lack of access to basic services, vulnerability to natural disasters, and limited economic diversification [14], according to the Table 1.

Table 1: Family Food Security/Insecurity

Location	Food insecurity			
	without food security	mild	severe	indicator
Monte Alto	46%	54%	0%	2.5
Ejido Villa Cuauhtémoc	30%	68%	3%	2.7
Ejido Esteros	40%	60%	0%	2.7
Estero de Barberena	40%	60%	0%	2.7
Esteros	47%	37%	17%	2.9
Pescadores	16%	79%	5%	2.9
Ejido Estación Colonias	27%	63%	10%	3
Los Presidentes	28%	67%	6%	3.1
Ejido Mata de Abra	19%	75%	6%	3.1
Morelos	39%	39%	21%	3.1
San Antonio	25%	56%	19%	3.2
Santa Elena	28%	63%	9%	3.3
Villas de Altamira	19%	67%	14%	3.3
Carrillo Puerto	9%	62%	19%	3.4
Bahía	24%	68%	8%	3.4
Cuauhtémoc	17%	79%	3%	3.5
Lomas del Real	0%	100%	0%	3.5
Nuevo Madero	23%	64%	14%	3.5
Rio Tamiahua	15%	73%	13%	3.6
Santo Tomás	17%	75%	8%	3.6
Felipe Carrillo Puerto	16%	68%	16%	3.7
Lagunas de Miralta	14%	86%	0%	3.9
La Pedrera	19%	47%	34%	4.1
Ejido 3 de Mayo	6%	75%	19%	4.1
El Champayán	7%	61%	32%	4.5

	Frequency	Percentage	Cumulative frequency	Cumulative frequency	Cumulative percentage	Cumulative percentage
0	36	5.4%	36	161	5.4%	24.3%
1	58	8.7%	94		14.2%	
2	67	10.1%	161		24.3%	
3	265	40.0%	426	418	64.3%	63.0%
4	81	12.2%	507		76.5%	
5	72	10.9%	579		87.3%	
6	63	9.5%	642	84	96.8%	12.7%
7	21	3.2%	663		100.0%	
	663	**100.0%**		**663**		**100.0%**

VII.PROPOSED MODEL

The proposed model, based on advanced optimization techniques, will include components such as transportation and storage infrastructure, distribution routes, community sales points, and community participation mechanisms. Furthermore, it will seek to integrate corporate social responsibility programs as catalysts for structural change in rural food management. This model is presented in Fig. 5.

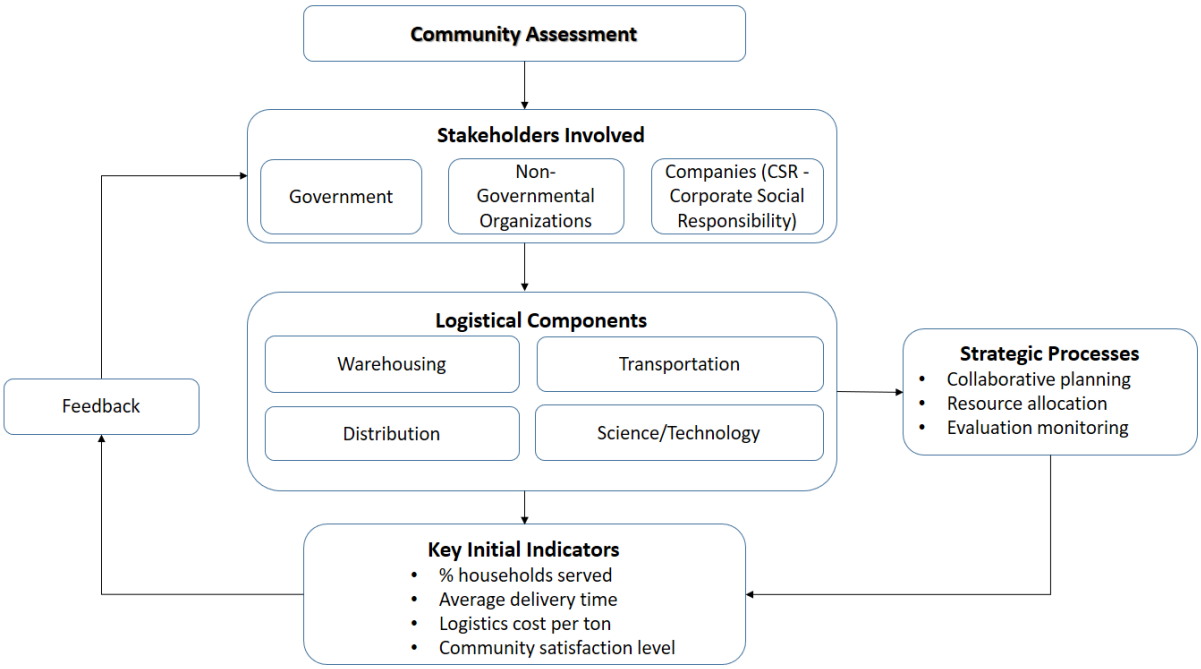


Figure 5: Components of the proposed model

Fig. 5 represents the systemic logistics management model for social impact projects. It is a flowchart that structures how to transform an identified social need into a tangible, measurable, and sustainable solution through intersectoral collaboration and operational efficiency.

1. The Entry Phase: Community Diagnosis

This is the research and situational analysis phase. Before mobilizing any resources, the problem must be understood; here, real needs, demographics, vulnerabilities, and estimated demand are defined. Without this diagnosis, any subsequent logistical effort would be inefficient (allocating resources where they are not needed) or ineffective (allocating inadequate resources).

2. Governance and Collaboration: Stakeholders

The flow descends to the decision-making core, composed of three fundamental pillars:

Government: Provides the legal framework, facilitates permits, and often provides public infrastructure and involvement with programs that address food security in rural areas.

NGOs (Non-Governmental Organizations): They contribute field knowledge, empathetic connection with the community, and volunteer human capital.

Companies (CSR - Socially Responsible Companies): They contribute financing, technology, transportation, and, crucially, logistical know-how and efficient management.

Analysis: This section suggests that the model is neither paternalistic nor unilateral; it is based on Intersectoral Synergy (or the Social Triple Helix model), where the combination of resources optimizes the outcome.

3. The Operational Engine: Logistical Components

This is the technical execution phase ("the how"). It is divided into four quadrants:

Storage: Inventory management, preservation of inputs (cold chain in this case for food), and security of goods.

Transportation: The physical movement of resources from the origin to the delivery point (last mile).

Distribution: The final delivery to the beneficiary. This involves the logistics of equitable distribution.

Science/Technology: This is a modern differentiator. It involves the use of traceability software, data analysis for optimal routes, advanced optimization, and information systems to prevent resource leaks.

4. The Management Layer: Strategic Processes

On the right, connected to logistics and indicators, is the "brain" of the system:

Collaborative Planning: Ensures that the three actors (Government, NGOs, and Businesses) are aligned in terms of time and methods.

Resource Allocation: Optimizing budgets and materials to maximize reach (doing more with less).

Evaluation Monitoring: Constant supervision to ensure that the logistics operation adheres to the plan.

5. Measuring Results: Key Performance Indicators (KPIs)

The system culminates in (and is simultaneously evaluated by) quantifiable results. The diagram proposes a mixed Balanced Scorecard (social and economic):

% of households served: Coverage Indicator (Social Effectiveness).

Average delivery time: Agility indicator (Operational efficiency).

Logistics cost per ton: Financial efficiency indicator.

Community satisfaction level: Perceived quality indicator (Qualitative impact).

6. The Improvement Cycle: Feedback

The arrow connecting the "Indicators" back to the "Stakeholders" and "Logistics Components" closes the cycle.

This makes the model a dynamic system of continuous improvement. If the "Satisfaction Level" is low or the "Cost" is high, the information is returned to the Stakeholders, who must adjust the Strategy or Logistics for the next cycle. This prevents the project from stagnating and allows for adaptation to changes in the environment.

In this way, the model implies that social aid is not just "goodwill"; it is a complex logistical engineering operation. It proposes that successfully serving a community requires integrating the technical capacity of private companies, the social sensitivity of NGOs, and government regulation, all linked through technology and rigorously measured to ensure that aid arrives on time, at the lowest possible cost, and with the greatest social impact.

VIII.DISCUSSION

From a scientific perspective, this research significantly contributes to closing knowledge gaps regarding the application of logistics models in rural contexts with food insecurity. Although studies on humanitarian and development logistics exist, few have been contextualized for Mexican rural communities, and even fewer have integrated the participation of public and private actors under shared social responsibility frameworks.

The proposed model is based on contemporary theories of supply chain management, logistics optimization, and multidimensional food security, which will allow for the generation of a robust and replicable theoretical framework. Furthermore, the research will incorporate tools such as GIS [11] and analysis multivariate statistical analysis and qualitative thematic analysis techniques were employed, enriching the methodological rigor. The results are expected to generate new logistical and socioeconomic indicators to evaluate the impact of food security interventions, as well as simulation models that can be used in future research.

Therefore, academically, this research will contribute to the body of literature on logistics and supply chain management in a food security context, providing a novel theoretical and methodological foundation that can be applied to study other rural regions with similar problems.

The social impact of this research is profound and transformative. Food insecurity in rural areas like Altamira not only affects nutrition but also perpetuates cycles of poverty, limits access to education, and deteriorates community health. By proposing a logistics model adapted to local conditions, the aim is to improve the quality of life of rural families through:

- Greater availability of nutritious food.
- Reduced access costs.
- Decreased food waste.
- Strengthening of local economies.
- Active community participation in food management.

Furthermore, the shared social responsibility approach promotes collaboration between sectors, which can lead to more inclusive public policies and sustainable intervention programs.

The model can also serve as a basis for replicating strategies in other rural communities, generating a multiplier effect in the fight against hunger and poverty.

Socially, the implications and the proposed model, focused on the shared responsibility approach, can provide local government and non-governmental organizations with a basis for public policies and the design of intervention programs that directly benefit the most vulnerable communities in the area. It can become a starting point for developing strategies and using distribution logistics to design programs to combat food insecurity.

The proposal aligns with several priority programs of the Mexican government, especially those related to:

- Food security (SEGALMEX, SADER).
- Social welfare (Ministry of Welfare).
- Sustainable rural development.
- Poverty and inequality reduction (CONEVAL).
- Corporate social responsibility (ESG –Environmental, Social, and Governance– and certifications).
- The study aims to impact the following PRONACES (National Programs for Community Economic and Social Development):

Food Sovereignty: This directly addresses food insecurity in rural communities, focusing on access to and availability of food. This PRONACES seeks to guarantee the right to adequate food, especially in marginalized areas, through sustainable and participatory strategies. The direct connection to the proposal lies in:

- Diagnosis of food insecurity.
- Optimization of the food supply chain.
- Community participation in food management.

Education: Although not the primary focus, the model includes community training and the generation of applied knowledge, which aligns with strengthening local capacities and education for development. The connection between Education and the proposal is:

- Training in community logistics.
- Transfer of technical and social knowledge.
- Active participation of local stakeholders in the design of the model.

Socio-ecological Systems and Sustainability: Sustainable rural development, infrastructure adapted to the environment, and the reduction of food waste are considered, all of which are linked to the sustainability of socio-ecological systems. The connection to the proposal is as follows:

- Design of logistics routes adapted to the rural environment.
- Reduction of food waste.
- Strengthening of local economies.

By generating empirical evidence on logistical and socioeconomic barriers, the research can inform the design of data-driven public policies, contributing to the formulation of national strategies to combat food insecurity.

It also aligns with the Sustainable Development Goals (SDGs), particularly SDG 2 (Zero Hunger), SDG 9 (Industry, Innovation and Infrastructure), and SDG 17 (Partnerships for the Goals), strengthening Mexico's commitment to the 2030 Agenda [15].

IX.CONCLUSIONS

The research conducted allows us to draw fundamental conclusions regarding the interaction between logistics engineering and the social problem of hunger in marginalized rural environments:

1. Logistics as a determinant of food security: It is concluded that food insecurity in the rural area of Altamira is not solely a consequence of a lack of agricultural production, but is strongly correlated with structural inefficiencies in the supply chain. Deficient infrastructure, the lack of cold chains, and high transaction costs in the "last mile" act as barriers to access, perpetuating the cycle of poverty and nutritional vulnerability.

2. Innovation through Shared Social Responsibility (SSR): The proposed model demonstrates that isolated intervention by the public sector is insufficient. Integrating a Shared Corporate Social Responsibility framework is both viable and necessary. By linking the logistical and technological know-how of the private

sector with the social awareness of NGOs and the regulatory capacity of the government, a resilient ecosystem is generated, capable of sustaining efficient, rather than merely providing assistance, humanitarian aid operations.

3. Relevance of the Advanced Optimization Model: From an engineering perspective, the model's design validates the use of advanced optimization techniques and geographic information systems for decision-making in social contexts. The structuring of key performance indicators (KPIs) focused on coverage, agility, and logistical cost per ton provides a robust quantitative framework for measuring the real impact of interventions, bridging the gap between logistics theory and humanitarian practice.

4. Social Impact and Strategic Alignment: Finally, the study confirms that applying engineering principles to complex social problems directly contributes to food sovereignty. The proposal aligns with the National Food Security Programs (PRONACES) and the 2030 Agenda, offering a replicable methodology for other rural regions with similar characteristics. The model not only seeks to deliver food but also to strengthen local economies and empower the community through active participation in managing its own food security.

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