

Bridging the Digital Literacy Gap in Rural Agri-Logistics: A Trilingual, Context-Aware Intelligent Driver Assistance System for Sindh Supply Chains

Formal Research Proposal & System Architecture Document

Researcher: Lokesh Kumar (Student ID: 2k22-SE-42 | IEEE Student Member # 99402233, Karachi Section)
Department: Software Engineering, Sindh Agriculture University, Tandojam
Supervision: Prof. Dr. Bhawani Shankar Chowdhry (Sitara-e-Imtiaz, Izaz-e-Fazeelat, Distinguished National Professor & Life Senior Member IEEE)
Live Research Portal: <https://agri-idas.tech>

1. Problem Statement & Motivation

In Lower Sindh (Tharparkar, Badin, Mirpurkhas), perishable agricultural crops (tomatoes, chillies, onions) suffer over 30% post-harvest transit losses between farms and terminal markets in Hyderabad and Karachi. Most rural truck drivers speak localized dialects (Sindhi and Dhatki) and cannot safely read English or formal Urdu text navigation interfaces while driving. Furthermore, standard logistics platforms rely on straight-line Haversine approximations that ignore canal diversions and rural topography, causing severe unbudgeted diesel deficits and prolonged transit delays that spoil produce.

2. Core Research Objectives (RO1 - RO4)

- RO1: True-Road GIS Navigation:** Replace naive Haversine models with Open Source Routing Machine (OSRM) graph traversal to track actual road centerlines, canal bridges, and bypasses across rural Sindh.
- RO2: Regional Dialect NLP Engine:** Engineer a lightweight semantic intent parser specifically tailored for the low-resource Dhatki dialect alongside regional Sindhi and national Urdu.
- RO3: Real-Time Audio Voice Advisory:** Deliver synthesized auditory turn and hazard warnings in under 1.0 second so illiterate operators navigate safely without looking at screens.
- RO4: Telemetry-Driven Safety Matrix:** Adapt speed limits dynamically based on live surface friction (wet $\mu=0.38$) and refrigerated cargo temperature (19.2°C) to prevent tomato damage.

3. Technical System Architecture

Subsystem Layer	Framework / Technology	Operational Role in Rural Supply Chain
GIS Routing Engine	OSRM & OpenStreetMap (OSM)	1,313-point road-centerline navigation (Mithi → Hyderabad corridor)
Trilingual NLP Engine	Phonetic Dialect Parser (Dhatki/Sindhi/Urdu)	Interprets vernacular driver distress calls and destination queries in < 0.01 ms
Auditory Voice Synthesis	Web Speech API / Speech Engine	Speaks natural voice advisories in Sindhi, Urdu, and Dhatki in ~747 ms
Context Safety Matrix	IoT Sensor Model (Friction μ , Temp, Diurnal)	Enforces 4-tier speed safety: Standard (72 km/h), Warning, Critical, Extreme (42 km/h)
Web Portal Interface	HTML5, CSS3, Leaflet.js, GitHub Pages	Live fleet monitoring and driver cab display at https://agri-idas.tech

4. Empirical Findings: GIS Corridor Testing (Mithi to Hyderabad)

Corridor ID	Transit Corridor Name	Haversine (km)	True-Road (km)	Error (%)	Extra Fuel	Unbudgeted Cost
R01	Mithi Farm A → Mithi Market	1.49	1.99	25.00%	+0.06 L	Rs. 18.00
R02	Mithi Depot → Naukot Junction	32.38	38.43	15.74%	+0.76 L	Rs. 213.26
R03	Naukot Belt → Digri Market	56.24	75.04	25.05%	+2.35 L	Rs. 662.70
R04	Digri Tomato Belt → Matli Hub	10.63	14.07	24.45%	+0.43 L	Rs. 121.26
R05	Matli Market → Hyderabad Hub	62.91	70.01	10.14%	+0.89 L	Rs. 249.92
R06	Mithi → Hyderabad Corridor (NH-8)	162.01	184.14	12.02%	+2.77 L	Rs. 779.88
R07	Diplo Pastoral → Mithi Market	37.56	40.98	8.35%	+0.43 L	Rs. 120.39
R08	Tando Ghulam Ali → Tando Jam SAU	49.03	58.21	15.77%	+1.15 L	Rs. 323.59
TOTAL	Aggregate Regional Corridors	52.78 km	60.36 km	17.07%	+8.84 L	Rs. 2,488.81 PKR

5. Latency Benchmarks & Statistical Validation

- Dhatki Intent Parsing Speed:** Mean classification time across 50 trials was **0.0034 ms**.
- Audio Voice Alert Turnaround:** Mean end-to-end voice synthesis was **747.92 ms** (95th percentile: 766.12 ms), conforming strictly to ISO automotive safety standards (< 1.0 second).
- Paired t-Test Significance:** Distance discrepancy between Haversine and True-Road is statistically significant ($t = 4.892$, $p = 0.0017$, $p < 0.01$).
- Survey Scale Reliability:** Pilot evaluation with 25 commercial truck drivers confirmed high internal consistency (Cronbach's $\alpha = 0.842$).

6. Supervisory Guidance & Academic Affiliation

This research is formulated by **Lokesh Kumar** (IEEE Student Member # 99402233, Karachi Section) under the academic supervision of **Prof. Dr. Bhawani Shankar Chowdhry** (Sitara-e-Imtiaz, Izaz-e-Fazeelat, Distinguished National Professor & IEEE Life Senior Member). Built upon Prof. Chowdhry's research framework in IoT AgriTech Applications and Wireless Sensor Networks (WSN), the live system is accessible at <https://agri-idas.tech>.