Proceedings of the IISE Annual Conference & Expo 2025
E. Gentry, F. Ju, X. Liu, eds.

From Farm to Food Hub:

Analyzing Logistics in Cooperative Agricultural Systems

Abstract ID: 9058

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Abstract

This study explores the logistical challenges within cooperative agricultural systems through an ongoing collaboration between researchers and practitioners at the Wisconsin Food Hub Cooperative (WFHC). Operating under a cooperative model, WFHC enables small-scale farmers in rural regions to access shared logistics infrastructure, reducing individual costs while expanding their market reach. Drawing from interdisciplinary perspectives and fieldwork conducted in partnership with WFHC members, this research examines the route operations required to collect products from dispersed farming locations for consolidation at the food hub. Using process mapping and workflow analysis, the study identifies the needs in route planning, pickup scheduling, and load optimization. Further, this collaboration highlights opportunities to enhance the efficiency and sustainability of product aggregation. Findings contribute to resilient, community-driven food networks while supporting underserved farming communities.

Keywords
Case study paper, Cooperative Logistics, Rural Supply Chains, Sustainable Food Systems, First-Mile Product Aggregation.

1. Introduction

In recent years, the demand for sustainable food systems has increased as consumers, policymakers, and researchers recognize the need for equitable and resilient food supply chains. Rural communities and supply networks that serve them face unique challenges in logistics, distribution, and market access, often struggling to compete with large-scale commercial food suppliers [1]. One critical approach to addressing these challenges is through collaborative logistics [2], where small-scale farmers work together, sometimes using the cooperative business model, to optimize resources, reduce costs, and gain collective bargaining power in competitive markets. A food hub cooperative (or co-op) is a farmer- and/or consumer-owned organization that provides a shared platform for food distribution and marketing, offering an alternative to conventional supply chains [3]. Unlike large agribusinesses, food hub co-ops focus on fair pricing, ethical sourcing, and direct farmer-to-consumer relationships. These cooperatives enhance first-mile product aggregation and last-mile delivery, ensuring that food from dispersed rural farms is efficiently collected, transported, and distributed while maintaining quality and reducing waste. Operating under a cooperative business model, the Wisconsin Food Hub Cooperative (WFHC) provides a shared logistics network that allows small farmers to pool resources and distribute their products in a profitable way for farmer-members in Wisconsin, as well as for other farmers participating in government food access programs [4]. Wisconsin has long been a key player in U.S. agriculture, contributing nearly $104 billion annually to the economy [5]. The state is home to over 58,000 farms, covering 13.8 million acres, with dairy, cranberries, corn, and ginseng among its leading commodities [5]. However, small-scale and diversified farmers often struggle with transportation and market integration due to infrastructure constraints, long distances between farms, and limited logistical resources. Hence, the WFHC was established to bridge this gap. Its cooperative model enables local producers to scale their operations without bearing the full burden of logistics costs, making sustainable and community-driven food networks more accessible. In addition, WFHC facilitates interactions between farmers and wholesale markets, ensuring that high-quality, locally grown food reaches consumers while supporting smallholder farmers. However, despite its advantages, WFHC, like other agricultural cooperatives, faces operational challenges. This study seeks to analyze the WFHC's route operations for farm product collection and consolidation. By documenting a route shadowing with WFHC drivers, this research provides firsthand observations of logistical hurdles including delays, and infrastructure barriers. This study also identifies key improvement areas in: (1) route planning and optimization: minimizing delays, improving fuel efficiency, and navigating rural road constraints, (2) pickup scheduling: ensuring timely aggregation while accounting for farmers' preparation constraints, and (3) load optimization: maximizing truck capacity and cold chain efficiency to reduce food waste and energy consumption. This case study highlights the potential role of industrial engineers in designing and refining sustainable supply chains for small farmers. By applying logistics optimization, engineering methodologies can contribute to increasing food supply resilience, reducing costs for farmers, and fostering a more equitable food economy.

2. Problem Statement

Small-scale farmers face significant barriers in a market dominated by large industrial farms, which benefit from economies of scale and established distribution networks. Logistical challenges in transportation and distribution further hinder small farmer's ability to compete. Food hub cooperatives like WFHC help bridge this gap by providing shared logistics infrastructure, enabling farmers to pool resources, streamline transportation, and access larger wholesale markets. However, WFHC faces operational hurdles that impact both farmers and the cooperative. Route shadowing revealed delays at farms and the hub, infrastructure constraints, and scheduling misalignment. Many farms are in remote areas with poor road access, requiring manual transport of produce, increasing labor and time costs. Pickup coordination is inconsistent, as farmers need hours to prepare shipments, often relying on family labor, while limited communication between farmers and drivers exacerbates scheduling inefficiencies. These challenges highlight the potential for industrial engineering solutions to enhance collaborative logistics. Route optimization, process mapping, dynamic scheduling, and cold chain logistics strategies can improve efficiency while maintaining WFHC's commitment to equitable food systems. Industrial engineers have a responsibility to support sustainable, community-driven supply chains, leveraging data-driven decision-making to improve food distribution operations and foster long-term resilience.

3. Route Shadowing

This study employs a route shadowing methodology to examine the logistical processes of the WFHC. Route shadowing is a qualitative research method that involves directly observing transportation operations to document workflows, identify potential inefficiencies, and better understand the challenges faced by logistics personnel. This approach was selected to provide firsthand insights into rural supply chain operations, capturing real-time decision-making, infrastructure constraints, and coordination efforts between farmers and WFHC drivers. Hence, on Friday, August 2nd, 2024 a researcher conducted route shadowing of a WFHC farm collection route in a separate vehicle, following the truck's movements without direct interference. This approach ensured external perspective while allowing for detailed documentation of the route's progression, timing, and environmental conditions. The WFHC truck was a 44-foot refrigerated semi-trailer, operated by a driver and an apprentice, tasked with picking up produce from farms, controlling temperature, and delivering the aggregated load to the food hub. The route began at 11:00 AM, where the truck prepared for the operations at an urban farm that served as the origin of the route. Stops included three additional rural farms, each with distinct logistical conditions, before ending the route at the WFHC hub. The researcher maintained a detailed timestamped log throughout the journey, documenting: departure and arrival times at each stop, navigation challenges, including GPS discrepancies and road access issues, wait times and loading durations at farms and the hub, temperature control practices for refrigerated storage, and truck maneuverability constraints. Figure 1 presents a timeline of key activities observed throughout the day.

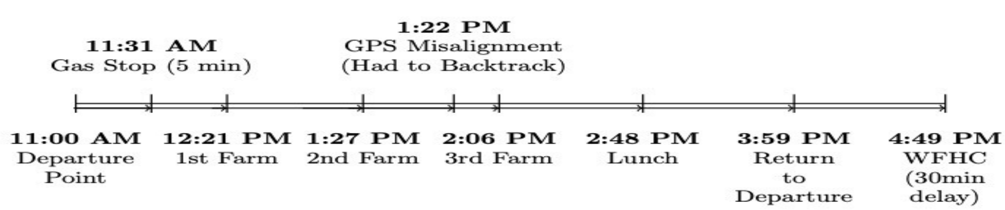

Figure 1. Route Timestamps

The route began at 11:00 AM at the original departure point, where the driver and apprentice arrived shortly after at 11:20 AM, loaded empty pallets, and activated the refrigeration system. Following a brief stop at a gas station from 11:25 to 11:36 AM, the truck proceeded to the first farm, arriving at 12:21 PM. Due to narrow roads, the vehicle had to park roadside, requiring farmers to manually transport their harvest for loading. By 12:52 PM, the truck departed with two loaded pallets. At 1:22 PM, the second farm was reached; however, a GPS misalignment led the truck to an incorrect location, requiring a backtrack before arriving at the correct stop at 1:27 PM. Loading was completed by 1:51 PM, at which point the truck's refrigeration settings were adjusted. The third and final farm, situated in a muddy and narrow alleyway, was reached by 2:06 PM, requiring careful maneuvering. After loading one pallet, the truck departed at 2:33 PM, with additional time spent backing out of the alley at 2:40 PM. A scheduled lunch break occurred at 2:48 PM, after which the truck resumed its journey at 3:30 PM, returning to the departure point at 3:59 PM. Following the pickup of additional boxes, the truck proceeded to the food hub at 4:10 PM, where a 30-minute docking delay extended the trip before the route was completed at 4:49 PM.

4. Findings and Analysis

The route shadowing of the Wisconsin Food Hub Cooperative (WFHC) collection process revealed several logistical challenges that impact both operational efficiency and farmer participation. These challenges primarily stem from navigation challenges, infrastructure barriers, and scheduling misalignments. One area of opportunity observed during route shadowing involved the accuracy of GPS navigation compared to actual farm locations. While the truck followed a predetermined route, discrepancies between mapped locations and real-world farm access points led to unplanned adjustments. This was particularly evident at the second farm stop, where the truck initially followed an incorrect entry point, requiring a reverse maneuver along a dirt road before reaching the intended destination. On a similar note, the physical landscape surrounding the farms also presented unique considerations. Three of the four farms were situated in locations where road conditions influenced the loading process. At the first stop, for example, the farm's position on a steep incline with narrow roadways necessitated that farmers transport their harvest to the roadside for collection. Similarly, the third stop involved maneuvering through a tree-lined, muddy alley, where space constraints required careful vehicle positioning. These observations highlight an opportunity to explore adaptive vehicle deployment strategies or infrastructure enhancements that can further support seamless product aggregation, especially in diverse rural terrains. Coordination between farmers and transport schedules is another key area where process refinement may yield significant benefits. Farmers reported that preparing and packing produce often required several hours, with some relying on small family units, including young children and elderly members, to complete these tasks. The variability in preparation times is taxing on the logistics and coordination of pick up routes as logistics personnel must ensure that trucks do not arrive before the produce is harvested and ready, hence avoiding extended wait times. Additionally, at the food hub, the truck was required to queue before accessing the docking station, adding extra time to the overall trip duration. Hence, implementing scheduling tools that incorporate dynamic updates from farmers and real-time adjustments to truck arrival times could improve overall synchronization and reduce idle periods. Additionally, while refrigeration units were activated at the beginning of the trip, adjustments to higher cooling settings were made after the second stop. Therefore, ensuring that optimal refrigeration settings are engaged prior to departure and consistently maintained throughout the trip could further strengthen temperature control, supporting product freshness and farmer confidence in the transport process. This also means there is potential for automatic scheduling or sensors that may reduce the manual interventions in the process.

5. Conclusions and Final Thoughts

The Wisconsin Food Hub Cooperative (WFHC) plays a critical role in supporting small-scale farmers by providing shared logistics infrastructure and wholesale market access. This study highlights opportunities for collaboration between food hub cooperatives and industrial engineers to enhance efficiency, sustainability, and scalability. The observed challenges are common in decentralized food supply chains and present opportunities for process optimization. Potentially, by integrating and tailoring routing models, WFHC can refine route planning, reducing travel time and fuel consumption. Mixed Fleet Routing strategies could also allow for flexibility in farms' access with road constraints. Additionally, Integer Linear Programming (ILP) models and Dynamic Scheduling Systems (DSS) could improve pickup coordination, improving interactions between farmers and drivers. To strengthen cold chain reliability, IoT-based temperature monitoring and pre-cooling protocols could enhance product quality while maintaining cost efficiency. This study underscores the areas of opportunities for industrial engineering in collaborative food logistics. By combining practical experience from WFHC with data-driven methodologies, there is immense potential for innovation in sustainable food distribution. Strengthening this collaboration will not only improve WFHC's operational resilience but also contribute to the long-term viability of small-scale farming in competitive markets.

Acknowledgements

The authors would like to express their gratitude to the employees and farmer members of the Wisconsin Food Hub Cooperative (WFHC) for their collaboration and invaluable insights throughout this study. Special thanks to the farmers who generously shared their time and experiences, as well as the drivers and logistics personnel who allowed us to observe their operations firsthand. Their dedication to strengthening local food systems has been instrumental in shaping this research. This work was supported in part by NSF-AI ICICLE OAC-2112606 and NSF-AI AI4OPT 2112533. The findings and conclusions presented in this paper are those of the authors and do not necessarily reflect the views of the funding agencies.

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