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Optimizing the locations of food-distribution businesses

A summary of "Wholesale hub locations in food supply chains" by Hamideh Etemadnia[a], Ahmed Hassan[b], Stephan Goetz[a] and Kaled Abdelghany[b]. Published in *Transportation Research Record*, No. 2379, 2013.

Food travels from farm to consumer in multiple ways. In the case of farmers markets, many producers bring their products directly to consumers themselves. But most food travels to consumers through a supply chain—a network of intermediary businesses that process, package, and/or transport the food to retail establishments where consumers purchase it. In general, more intermediaries are involved when more steps are required to make a product ready for final purchase. The path food follows from its production location to its final retail sales location can vary widely in terms of efficiency and transportation costs, depending on the number of intermediaries involved and the distances between them. Because efficient food supply chains can result in lower food prices, a goal of food-distribution researchers is to identify ways to improve their efficiency.

Objectives

In this study, the researchers focused on wholesale distributors (WDs)—intermediary businesses that provide the link between food-processing facilities (e.g., slaughter facilities) and food retailers when a direct link is not possible or is too costly. WDs serve several purposes. In addition to transporting food, they can sort and consolidate food from multiple producers and store it properly before delivering it to retailers. Optimally located WDs can reduce overall costs within the supply chain by maximizing the number of producers and retailers served while also minimizing transportation costs. The authors of this study developed a mathematical model that would allow them to identify the optimum number and location of WDs in any food supply chain. The researchers applied the model to the Northeast U.S. meat supply chain, to determine whether the existing WDs serving this supply chain are located optimally.

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The study

The researchers constructed a mathematical model that simulates the best way to allocate WDs in a county-level network to minimize transportation costs. Because optimal allocation may require adding new WDs to a supply chain network, the model also takes into consideration the costs associated with constructing new distribution facilities.

The model was built to define the optimal number and location of WDs based on the location of production (meat-processing and slaughtering) facilities and retail sales facilities in a given network. The model uses data on existing retail and production locations, and applies several assumptions on how the WDs will connect them:

- each WD serves production locations and retail locations;
- the total distance traveled between production and retail locations should be the least possible;
- the WDs are closer to the retail locations than to the production locations;

- there is a limit to the distance food can travel between WDs and their final retail location; and,
- all production and retail locations are connected to at least one WD.

The model also allows the researchers to look at various "what if" scenarios and their effects on WD number and location. For example, the model allows for adjusting the distance that food travels, the size (capacity) of the WDs, gas and land prices, and road conditions within the supply chain network.

The researchers then applied their model to examine the existing meat supply chain in the Northeast U.S., which comprises 433 counties. Using County Business Patterns data from the U.S. Department of Commerce, they identified 186 counties with slaughtering or meat-processing facilities, and 218 counties with retail meat markets. Inserting this information into their mathematical model, they calculated the optimal number of WDs required to connect the production facilities — in this case the counties where meat-processing or slaughter facilities are located — with retail markets and their locations within the network. They conducted this calculation in several different series, adjusting some of the parameters in each series to see how the number and location of WDs changes under different circumstances.

Findings

The analysis of the Northeast U.S. meat supply chain shows how the optimal number and location of WDs changes based on a number of factors, including distributor size and capacity, road conditions and gas prices. The researchers tested four scenarios. The first three scenarios examined how the optimal number of WDs in the network is affected by WD capacity (amounts of product that it can handle, in tons) and travel distance (from production location to WD, and from WD to retail location, in miles).

In the first scenario, the researchers assumed unlimited WD capacity and unlimited travel distance. They found that only two WDs were needed to serve all of the region's production and retail locations in the most cost-effective manner. In the second and third scenarios, they altered these assumptions. In scenario two (see Table 1), they left travel distance unaltered but placed limits on WD capacity, which resulted in the need for an increasing number of WDs as capacity decreased.

Table 1: Scenario 2—Unlimited travel distance combined with limited WD capacity

Maximum distance, in miles		WD capacity (in tons)	Optimal # of WDs
Production → WD	WD → Retail location		
Unlimited	Unlimited	300	6
Unlimited	Unlimited	150	11
Unlimited	Unlimited	80	20
Unlimited	Unlimited	40	39

In scenario three (see Table 2), they considered a maximum WD capacity of either 80 or 150 tons, and then placed a limit on travel distance. In this scenario, the most restrictive travel limits resulted in the need for the greatest number of WDs.

Table 2: Scenario 3—Restricted travel distance combined with limited WD capacity

Maximum distance, in miles		WD capacity (in tons)	Optimal # of WDs
Production → WD	WD → Retail location		
300	300	150	11
300	200	150	13
300	100	150	29
200	100	150	29
200	60	150	72
150	60	150	77
200	60	80	73
150	60	80	82

The fourth scenario examined the effects of road conditions and fuel prices on the location of WDs. Road conditions can change based on their level of service, accessibility, and capacity. The researchers simulated improvements in road conditions, and found that when more roads were improved, fewer WDs were needed to serve the network.

Conclusion

The mathematical model developed in this study is capable of suggesting ways to consolidate WDs for efficient delivery to retail sites, and enhances our understanding of how the optimal number and location of WDs in a food supply chain may change under different circumstances. This knowledge can lead to improved decision making. For example, knowing the optimal locations of WDs may be useful to private-sector firm owners planning to open new distribution businesses, or to change the locations of existing ones; using this knowledge may help them to maximize profits or to lower producers' costs through aggregation.

Similarly, policy makers can use the model to assess the effect of various definitions of "locally or regionally produced foods." There are many different definitions of local and regional, so using the model could help people decide which definition they preferred for their own purposes. For example, officials who want to promote regional agriculture can use the model to test how limiting to varying degrees the distance food travels between production and retail sales locations would necessitate changes to their existing distribution structure in order to efficiently distribute regional foods.

This model considered some, but not all factors affecting a food supply chain. Therefore, future research using similar models but different variables will provide additional information about how to improve the efficiency of food supply chains. ❖

About the EFSNE project

The work described here is part of a larger research project called "Enhancing Food Security in the Northeast through Regional Food Systems" (EFSNE). From 2011 to 2017, the EFSNE project engaged more than 40 partners at multiple universities, non-profits and government agencies around the question of whether greater reliance on regionally produced food could improve food access in low-income communities, while also benefiting farmers, food supply chain firms and others in the food system. Learn more at http://agsci.psu.edu/research/food-security.

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