Computational 'short cuts' offer fast answers to complex supply chain problems

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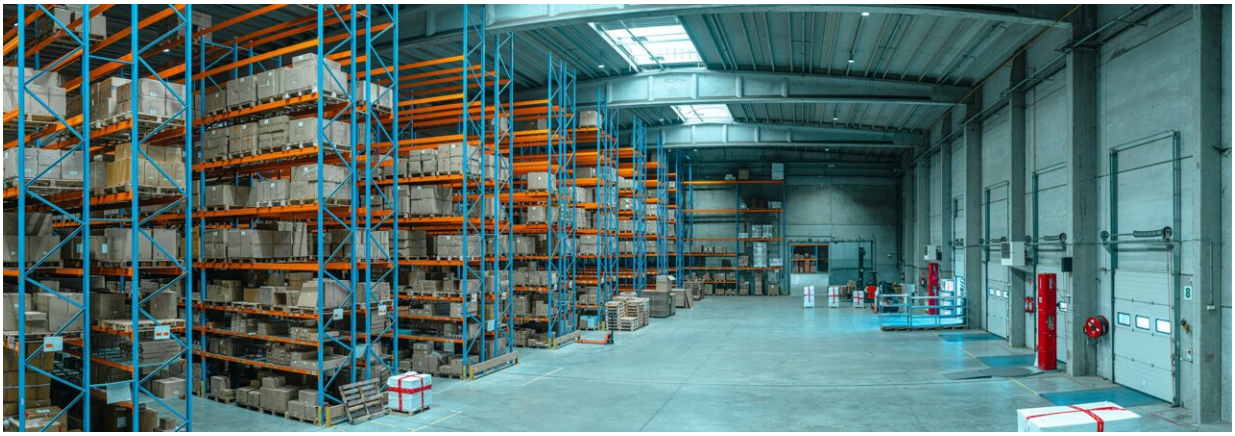

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Supply chain networks can be incredibly complex, with multiple manufacturing and distribution points—and the location of each node in those networks has a significant effect on everything from profitability to product cost to environmental impact. New research from North Carolina State University shows that efficient mathematical tools serve almost as well as more computationally demanding optimization models for determining the best places to locate elements in a supply chain, and can provide businesses with the relevant information far more quickly.

"Our work focuses on supply chains that improve economic and environmental performance by embracing sustainability," says Amir

Sadeghi, first author of the study and a Ph.D. student in NC State's Edward P. Fitts Department of Industrial and Systems Engineering.

"We looked at supply chains where elements of their products can be reused—such as printing technologies that reuse printer cartridges. These supply chains involve multiple manufacturing facilities, as well as many more distribution sites where consumers can both buy the products and return them for recycling or reuse. These multi-level supply chains are extremely complex, and the location of every point in the supply chain has significant ramifications in terms of cost, transportation time, and so on.

"While there are models that allow us to identify the exact optimal solution for where each point in the supply chain should be located, those models are computationally demanding. So we wanted to see how well more computationally efficient tools might perform, and whether they could be a suitable replacement for use in making supply chain management decisions."

Specifically, the researchers wanted to test the performance of two well-established heuristics, which are algorithm "shortcuts" capable of providing a good—but not necessarily optimal—answer to a complex problem quickly. They compared these two heuristics, which are called the Grey Wolf Optimizer (GWO) and the Whale Optimization Algorithm (WOA), against a computational model capable of finding the exact optimal solution. The researchers tested the heuristics against the exact optimization model for 15 different problems, reflecting a range of multilevel supply chain challenges.

The heuristics and the exact optimization model were all designed to find the best sites for every point in a supply chain, and then determine the cost of putting that supply chain in place. All three tools account for many variables that influence cost, such as transportation distance and

real estate and construction costs.

The researchers were surprised at how well the heuristics worked. There was some variability in the performance of the heuristics, depending on the specific supply chain challenge used in each test. However, at their best, the GWO was able to establish supply chain sites with costs that were within 0.01% of the exact optimization model while the WOA's costs were within 0.07% of the exact optimization model. And, on average, the heuristics were able to provide their solutions in about half the time of the exact optimization model.

"If you have an established supply chain, and one of your nodes drops out unexpectedly—a store closes, a manufacturing site is shut down by flooding, etc.—you need to act quickly to reestablish the supply chain," says Sadeghi. "If it's a complex supply chain—and you don't have access to a supercomputer—there may be a significant advantage in using a heuristic that can give you a very good answer about where to replace a missing link within hours, rather than waiting days to run an exact optimization model."

The researchers also found an unexpected advantage to the heuristics—they were more robust than the exact optimization model. In practical terms, that means that the answers provided by the heuristics were more likely to hold up when some of the variables changed. For example, if there was a slight shift in the location of a node in a supply chain network created by a heuristic, there would be a slight shift in the related cost. However, similar changes in supply chain networks developed by the exact optimization model were more likely to cause significant shifts in cost.

"Altogether, our findings here suggest there may be significant advantages for supply chain managers in adopting the use of heuristics," says Rob Handfield, who co-authored the study.

"We don't expect anyone to abandon the use of exact optimization models for long-term planning, but at the very least heuristics may be a useful way of testing the robustness of 'optimal' networks," says Handfield, who is the Bank of America University Distinguished Professor of Operations and Supply Chain Management in NC State's Poole College of Management. "And heuristics may be particularly valuable for supply chain managers who are forced to respond rapidly to unexpected disruptions in their networks."

The paper, "Grey Wolf Optimizer and Whale Optimization Algorithm for Stochastic Inventory Management of Reusable Products in a Two-Level Supply Chain," is published in the open-access journal *IEEE Access*.

More information: Amir Hossein Sadeghi et al, Grey Wolf Optimizer and Whale Optimization Algorithm for Stochastic Inventory Management of Reusable Products in a Two-Level Supply Chain, *IEEE Access* (2023). DOI: 10.1109/ACCESS.2023.3269292

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