JPR Japan Pallet Rental Corporation　Gunma University

Press Release

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Japan Pallet Rental Corporation

National University Corporation, Gunma University

Rapid Listing of Combinations of Transport Routes with High Cooperative Effects
Development of Joint Transport Matching Technology

Japan Pallet Rental Corporation (President and CEO: Naomi Kano, Head Office: Chiyoda-ku, Tokyo, hereafter referred to as "JPR") and National University Corporation, Gunma University (President: Yasuki Ishizaki, hereafter referred to as "Gunma University") have developed a joint transportation matching technology that instantly lists and proposes combinations of highly efficient combined transportation using a database with many registered transportation routes.

Labor shortages are emerging in the logistics industry, and there is an increasing need for joint transportation that allows more cargo to be transported with fewer trucks. The use of AI and other new technologies to improve matching efficiency is also drawing attention as advanced initiatives. However, building a system that can instantly respond to requests is difficult because even with computers, searching through the enormous number of combinations takes time.

Our newly developed technology makes good use of the hidden inequalities, such as the "distance axiom" known in the mathematical field, to narrow down the search range without sacrificing accuracy. The system can now instantly present highly efficient combinations of transportation routes that benefit from cooperation, supporting triangular transportation—in which a single truck sequentially handles three transports, and mixed transportation—in which freights from three transports are combined and transported simultaneously.

This technology has been installed as a core engine in the joint transportation matching system "TranOpt" provided by JPR. Service for general users was launched on October 21, 2021. In addition, the system also uses mathematical principles by adding a function that displays the predicted freight rates for joint transportation and fair cost-sharing among the partner companies.

■ Background

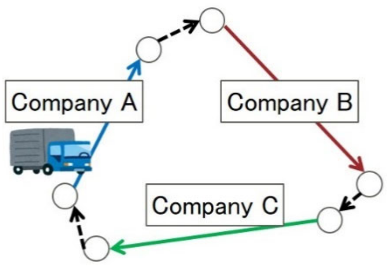
With the recent logistic crises and the shortage of truck drivers becoming apparent, improving labor productivity in the logistics industry has become an urgent issue. However, truck loading efficiency remains low, at less than 40% (*1) (trucks are loaded to only 40% of their capacity). One of the reasons for this is the vacant return trips in long-haul transportation. JPR has thus far supported efforts toward joint transport by companies in other industries and other measures to carry more cargo with fewer trucks. In October 2019, JPR began developing a common transportation matching system using AI technology in collaboration with Gunma University (*2) recognizing the importance of creating a system for deploying such initiatives throughout the logistics industry.

From October 2019 to March 2021, this development was funded by the New Energy and Industrial Technology Development Organization ("NEDO"). (The Project to Promote Data-Sharing in Collaborative Areas and Developing of AI Systems to Promote Connected Industries).

■ Technical issues

A series of transportation in which a single truck sequentially handles three transports is called "triangular transport." The higher the occupied vehicle ratio value, the better the efficiency (Figure 1). In contrast, transportation in which cargo is mixed together and transported simultaneously is known as "mixed transport." The smaller the reduction ratio, the better the efficiency (Fig. 2). If Company A requests matching, the system searches for partners (Company B and Company C) from its database and present a list of efficient triangular transportation and mixed transportation. If 10,000 transportation routes are registered, there are approximately 100 million combinations of two transportation routes. As it is also necessary to calculate the distance traveled, which differs according to the combination, a simple brute force calculation would take a long time using a calculator. In reality, one logistics company has multiple transportation routes. Thus, it is difficult for conventional methods to instantly respond to multiple matching requests from a single user or a series of requests from multiple users.

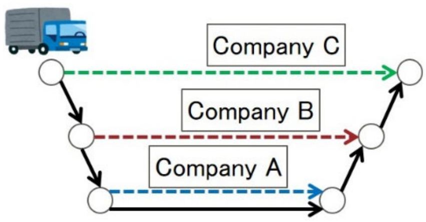
→ Transportation routes
- - → Returning Empty Vehicle



$$\text{Occupied vehicle ratio} = \frac{\text{Length of Solid Line}}{\text{Length of Solid Line+Dotted Line}}$$

Figure 1: Triangular Transportation

→ Joint Transportation Routes
- - → Routes without Joint Transport



$$\text{Reduction Ratio} = \frac{\text{Length of Solid Line}}{\text{Length of Dotted Line}}$$

Figure 2: Mixed Transportation

■ Developed Technology

Here's an easier explanation. In a marathon, after passing the 30 km point, the commentator says, "The possibility of breaking the event record has narrowed down to the top three runners." Let us examine the reasoning behind this. The result of the race is yet to be decided. However, we have the inequality that "each runner's pace per 10 km will not exceed the 10,000 meters world record." This inequality allows us to calculate backward to find the time for a runner to pass the 30 km point to break the record. Similar arguments can be made at other points. Therefore, even if there is undetermined information, we can effectively narrow it down by using the inequality behind it.

Suppose Company A requests a triangular transportation matching. In that case, the first route is Company A's, so we already know the first route's starting point, endpoint, and transportation distance. The second and third segments have not yet been finalized, as we are searching for partners. So we take advantage of the underlying inequalities. We can use the "distance axiom" known in mathematics (the distance to the destination via another point is greater than the distance directly to the destination, etc.). Using distance axioms skillfully, we could calculate backward the conditions required to achieve the specified occupied vehicle ratio. For instance, "the vacant distance between the first and seconds route must be less than or equal to this value," and "the distance of the second route must be greater than or equal to this value." Therefore, we can significantly narrow the search scope. By further devising the data structure and traversal order, faster enumeration becomes possible (*3).

■ Effects

Using approximately 17,000 anonymized transport data, we conducted experiments to enumerate efficient triangular and mixed transports. Although the response times varied depending on the conditions specified, we were able to accurately list combinations satisfying the given conditions 4,000 times faster (*4) for triangular transportation search and 1,500 times faster (*5) for mixed transportation search compared with simple brute force search. We can instantly respond to multiple matching requests from one user and a series of matching requests from multiple users by utilizing this technology.

■ Contribution of Mathematics

In recent years, the importance of the explainability of AI output results has been emphasized. Although this system uses advanced search logic, output results can be easily explained in the form of "all triangular transports with an occupied vehicle ratio of 95% or above" or "all mixed shipments with a reduction rate of 40% or less." The validity of that narrowing (without removing any combinations that satisfy the conditions) has been mathematically proven. Further, we have added a mechanism to calculate and display predicted transportation fares for triangular and mixed transportation to users and the fair cost-sharing among the three companies. Fair cost-sharing is calculated based on cooperative game theory (*6). Thus, we are also using the results of our predecessors in the field of mathematics and mathematical science in addition to the developed technologies.

■ Future Development

This technology is installed as a core engine in the joint transportation matching system "TranOpt" by JPR, and the service for general users was launched on October 21, 2021. We expect dramatic improvements in logistics as this technology will be used widely in the future.

***1)** General Principles of Logistics Policies (FY2021-FY2025)

***2)** The Social Mathematics Laboratory (Associate Professor Akifumi Kira) of the Faculty of Informatics (then Faculty of Social and Information Studies) is in charge of development.

*3) Patent rights jointly filed by Gunma University and JPR on October 20 (Japanese Patent Application No. 2021-171440)

*4) Calculated based on the average response time of 1,000 different matching requests to accurately list the 100 combinations with the highest occupied vehicle rate among those with an occupied vehicle rate of 85% or higher.

*5) Calculated based on the average response time of 1,000 different matching requests for the process of accurately listing 100 combinations with a reduction rate of 45% or less, starting with those with the lowest reduction rate.

*6) A mathematical theory that discusses the conditions under which cooperation among multiple actors can be achieved and the fair cost burden during cooperation

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