Private Transporters Cargo Allocation Dilemma

Jonathan Baraka, Logistics Assistant

Suzanne Bickes, Supply Chain Officer

UN World Food Programme, Goma, DR Congo, [September 29th, 2025]

1. Introduction to the context

Each month, for its logistics operations, WFP Goma field office allocates cargo tonnages to private transporters who carry the cargo to different distribution sites. The tonnage per transporter is allocated based on their average value of the contractual cargo share in percents and their monthly performance. However, distribution sites have different pay rates. The core of the cargo allocation dilemma then lies in determining the specific sites each transporter should serve and the exact tonnage they should carry to those sites. Consider two private transporters with identical contractual cargo allocations and performance. Suppose 100 tons must be distributed equally between them, with Site 1 requiring 50 tons at a rate of 1 USD/ton and Site 2 requiring 50 tons at a rate of 2 USD/ton. From a tonnage perspective, an equal allocation would assign 50 tons to each transporter. However, if one transporter delivers solely to Site 1 and the other to Site 2, their revenues would differ—50 USD versus 100 USD—resulting in unfairness. To ensure equity in both tonnage and revenue, a fairer approach is to allow each transporter to split their allocation, carrying 25 tons to Site 1 and 25 tons to Site 2. In this case, both transporters earn 75 USD, thereby achieving fairness. This allocation seems easy with few transporters, however when the number increases (18 transporters in the Goma case), calculations become complex. This paper investigates strategies to ensure equitable allocation of both tonnage and revenue among private transporters, aiming to minimize deviations and enhance overall fairness.

2. Current Solution

The current approach for achieving overall fairness in tonnage and revenue relies primarily on a trial-and-error method. An Excel sheet with adequate formula has been developed which contains constraints that need to be satisfied. The first constraint is that the tonnage required per site needs to be met and secondly, the difference between the average percentage of the contractual cargo share and performance of the transporter subtracted from the transporter's revenue percentage needs to be close to zero. While this method is effective in most cases, it is time-consuming and can become impractical when the number of sites increases significantly.

3. Proposed Method

This is a classical constraints satisfaction problem which seeks to achieve both revenue fairness and meet the to require at different sites. A set of mathematical notations will be formulated and then a Python script solution is written using linear programming. The solution is implemented for 18 transporters as is the case for Goma. It can easily be scaled.

3.1. Mathematical Formulations

Let:

- $i = 1, \ldots, 18\ index\ transporters$
- $j = 1, \ldots, m\ index\ sites$
- $S_j = total\ tonnage\ demand\ at\ site\ j$
- $r_j = rate(USD/ton)\ at\ site\ j$
- $p_i^{contract} = transporter\ i\ contract\ allocation\ percentage\ \ in\ fraction$

- $p_i^{perf} = transporter\ i\ perfromance\ in\ fraction$
- $monthly\ allocation\ percentage\ p_i = \frac{p_i^{contract} + p_i^{perf}}{2}\ (given)$
- $TotalTonnageT = \sum_{j=1}^{m} S_j$
- $Target\ (ideal)\ tonnage\ for\ tansporter\ i: t_i = p_i \cdot T$
- $Total\ revenue\ R = \sum_j r_j \cdot S_j$
- $Target\ revenue\ for\ transporter\ i: q_i = p_i \cdot R$

Decision variables:

$x_{ij} \geq 0: tons\ assigned\ to\ transporter\ i\ from\ site\ j$

Constraints:

a. Site capacities respected:

$$\sum_{i=1}^{18} x_{ij} = S_j \quad \forall j$$

b. Nonnegativity:

$$x_{ij} \geq 0 \quad \forall i, j$$

In instances where the tonnage per site is greater than zero($x_{ij} > 0$), two constraints have been added:

$x_{ij} \geq 10$ and $x_{ij} \leq y$ where y is the maximum tonnage a transporter can carry per site

The ideal fairness goals, which cannot always be met exactly since each transporter an ideal target tonnage t_i and a target revenue q_i but because the site S_j and rate r_j are fixed. It is usually impossible for each transporter to hit their exact target. So, the fairness goal is expressed as follows:

- $Tonnage\ fairness: \sum_j x_{ij} \approx t_i$
- $Money\ fairness: \sum_j r_j \cdot x_{ij} \approx q_i$

We can turn these two approximations into a minimization objective of deviations by introducing two auxiliary variables, u_i for tonnage deviation and v_i for revenue or money deviation.

- Tonnage deviation:

$$u_i = \left| \sum_j x_{ij} - t_i \right|$$

- Revenue deviation:

$$v_i = \left| \sum_j r_j \cdot x_{ij} - q_i \right|$$

Thus, achieving overall fairness for private transporters in both tonnage allocation and revenue ultimately reduces to minimizing this weighted sum which is the objective function:

$$min \quad \alpha \cdot \sum_i u_i + \beta \cdot \sum_i v_i$$

Where $\alpha, \beta \geq 0$ and they emphasize the degree of importance of either the tonnage fairness or revenue fairness. 1 is the greatest value of importance and 0 is the least value of importance.

4. Python Implementation

The PuLP library was used to solve the cargo allocation dilemma. It is a Python package for formulating and solving linear programming (LP) and mixed-integer linear programming (MILP) problems. It provides a clean syntax to define decision variables, constraints, and objective functions.

The code can be found here: https://github.com/jonathankashabira/WFP-Private-Transporters-Cargo-Allocation-Dilemma-.git

After running the code, you would get the following results about transporters and their different tonnages per site.

Result output:

Transporter	Target tons	Assigned tons	Target rev	Assigned rev
0	114.91	114.91	4627.20	4627.20
1	82.80	82.80	3334.31	3334.31
2	113.22	113.22	4559.16	4559.16
3	69.28	69.28	2789.93	2789.93
4	89.56	89.56	3606.50	3635.34
5	116.60	116.60	4695.25	4695.25
6	79.42	79.42	3198.21	3198.21
7	79.42	79.42	3198.21	3198.21
8	74.35	74.35	2994.07	2994.07
9	62.52	62.52	2517.74	2517.74
10	92.94	93.04	3742.59	3742.59
11	81.11	81.11	3266.26	3266.26
12	116.60	116.60	4695.25	4870.54
13	116.60	116.60	4695.25	4695.25
14	116.60	116.60	4695.25	4695.25
15	111.53	116.50	4491.11	4491.11
16	91.25	91.25	3674.54	3674.54
17	76.04	76.04	3062.12	3062.12

Targeted vs Assigned values

Transporter 0:	15.09	0.00	49.82	0.00	0.00	50.00	0.00	0.00
Transporter 1:	0.00	50.00	0.00	11.28	0.00	0.00	0.00	21.52
Transporter 2:	0.00	50.00	25.56	0.00	37.66	0.00	0.00	0.00
Transporter 3:	13.24	0.00	0.00	42.38	0.00	0.00	0.00	13.66
Transporter 4:	0.00	40.33	0.00	0.00	0.00	49.23	0.00	0.00
Transporter 5:	31.15	0.00	50.00	0.00	35.45	0.00	0.00	0.00
Transporter 6:	0.00	34.07	0.00	0.00	0.00	45.36	0.00	0.00
Transporter 7:	0.00	48.83	0.00	0.00	30.59	0.00	0.00	0.00
Transporter 8:	28.90	0.00	0.00	0.00	0.00	45.45	0.00	0.00
Transporter 9:	0.00	10.00	42.11	0.00	0.00	0.00	0.00	10.41
Transporter 10:	0.00	50.00	0.00	0.00	0.00	33.04	0.00	10.00
Transporter 11:	0.00	49.87	0.00	0.00	31.24	0.00	0.00	0.00
Transporter 12:	0.00	50.00	17.76	0.00	0.00	48.84	0.00	0.00
Transporter 13:	49.93	20.63	0.00	0.00	0.00	21.19	0.00	24.85
Transporter 14:	0.00	0.00	49.97	50.00	0.00	0.00	0.00	16.63
Transporter 15:	10.00	41.34	0.00	0.00	0.00	50.00	0.00	15.16
Transporter 16:	0.00	50.00	18.83	0.00	0.00	0.00	0.00	22.42
Transporter 17:	48.26	0.00	0.00	0.00	14.71	0.00	0.00	13.08

Tonnages of transporters per site with $y \leq 50$