

Introducing a Globally Unique Approach to

SECTORISATION AND FAIR COST ALLOCATION

for Post and Parcel Operations
with Combined and Individual Networks



1. INTRODUCTION

This paper gives comprehensive insights into a game-changing solution developed by EPG and the University of Bonn to solve the sectorisation problem, which is closely connected to the vehicle routing problem. EPG's solution is designed to face logistical real-world challenges, specifically for companies handling both postal mail and parcels in two separate delivery networks. Smarter sectorisation is powered by discrete mathematics and the research of Prof. Dr. Jens Vygen and his team.

The solution includes the implementation of sophisticated algorithms, mathematical models, and advanced optimisation techniques in EPG's route planning product Greenplan. Greenplan helps to design delivery areas, or sectors, and create more efficient routes within them, improving delivery speed and reducing costs.

1.1. ABOUT GREENPLAN

Greenplan is EPG's SaaS for route planning and execution for ground transportation. The initial building bricks of Greenplan were developed within DHL and together with the Institute of Discrete Mathematics of the University of Bonn – one of the world's leading mathematical institutes for mathematical optimisation. In 2022 Greenplan became independent of DHL and in 2023 became part of EPG (Ehrhardt Partner Group – a

world-wide leading logistics and supply chain solutions provider from Germany). Our main focus is creating software that plans and optimises routes for delivery companies. We help clients save money by reducing the number of vehicles on the road and the total kms driven. Greenplan's solutions are used by logistics companies worldwide, helping them make their deliveries faster and more reliable.



1.2 THE PROBLEM WE SOLVE HERE

Many logistics companies, especially those dealing with heterogeneous networks, e.g. letter network and parcel network, face the challenge of organizing their delivery areas efficiently (the so-called sectorisation problem). A delivery area being defined as a geographic area in which one tour delivers shipments on a regular/daily basis. Hence, one needs to split large territories into smaller, manageable sectors. The goal is to improve delivery efficiency by creating well-organized sectors and then planning the most optimal routes within those sectors.

This is particularly complex for postal or CEP (Courier, Express and Parcel Services) companies as they often have two separate delivery networks: one that handles both letters and parcels (the so-called combined network) and another that handles parcels only (the so-

called parcel network). These delivery networks have different strengths and weaknesses, and their routes need to be optimised differently. For instance, typically the combined network is more standardized and therefore more cost-efficient, whereas parcel deliveries often need more flexibility due to time-sensitive shipments and this is easier to realize within the more flexible parcel network.

Due to the fact that parcel shipments can be handled by both networks, one needs to take the decision which parcels to deliver by the parcel network itself and which parcels to deliver by the combined network. Greenplan addresses this challenge by designing sectors that meet the specific needs of each delivery network, and calculating this parcel split for the best trade-off between efficiency and quality.

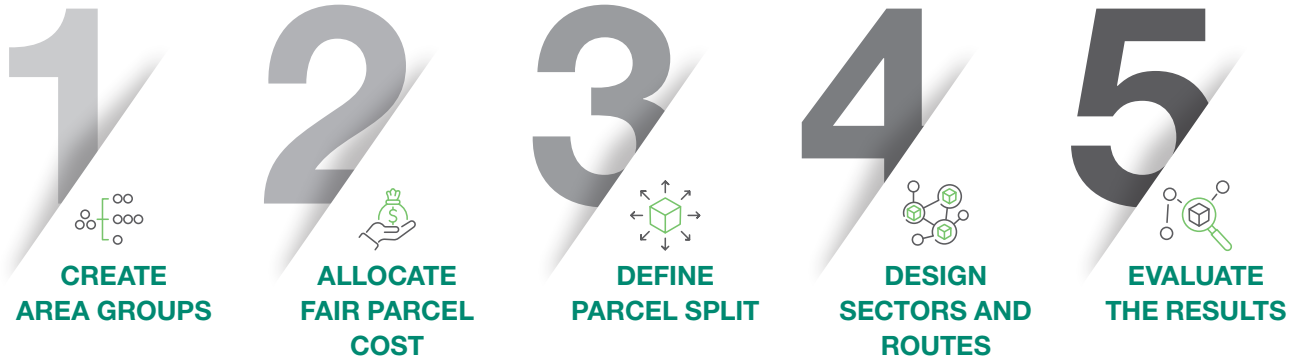
1.3 HANDLING THE TRADE-OFF BETWEEN QUALITY AND EFFICIENCY

The typical quality cost curve shows that after achieving a certain high-quality level, a further increase in quality KPIs demands an unproportional high amount of cost increase. Therefore, it is necessary to define the right cut-off point between acceptable quality level and costs. This problem in general demands an intense discussion

with the postal operator to define the sweet spot by looking at various solutions for different quality levels. Greenplan's core algorithm is highly flexible and thus parameters can be finetuned together with the postal operator in order to achieve the desired trade-off.

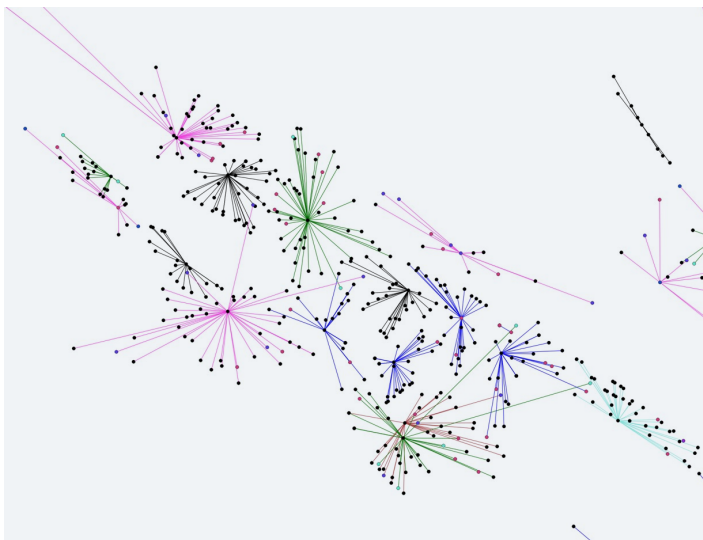
2. OUR SOLUTION IN FIVE STEPS

Greenplan's sector design is specifically tailored to the needs of postal and parcel operators. It builds on its heritage, years of experience in postal logistics, a custom-developed algorithm, as well as the R&D power of its partner the University of Bonn. The steps are carried out consecutively.



1 **CREATE AREA GROUPS**

We start by grouping delivery addresses/ housekeys within each postal code area. These groups are based on how close the addresses are to each other. The goal is to create manageable areas that make delivery easier. This process helps us break down the complexity of planning deliveries across a geographically large region massively. Each group of addresses/ housekeys is small enough to be handled efficiently but large enough to make the most of the available resources.

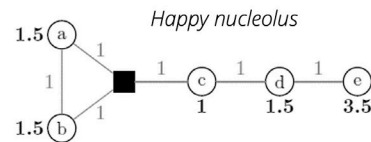
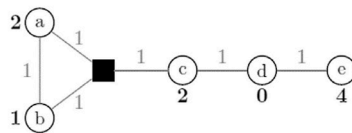


- | | |
|--------------------|----------------------------------|
| Area groups: | Time windows |
| Black vertices: | housekeys without time window. |
| Coloured vertices: | housekeys with some time window. |

2

ALLOCATE FAIR PARCEL COST – “THE HAPPY NUCLEOLUS”

The second step involves a unique approach to cost allocation called the "happy nucleolus". In simple terms, this helps us figure out how to fairly share the cost of delivering shipments in a given network e. g. parcels in a parcel network. So the total network costs are allocated to the single shipments in a “fair” way. Some parcels are more expensive to deliver because of their location, time constraints, or delivery volume. For example, parcels in remote areas might cost more to deliver because they are farther from the depot. The happy nucleolus is a concept borrowed from cooperative game theory, and it allows us to calculate how much each parcel should contribute to the overall delivery cost. This concept has been introduced by our development partner the University Bonn and is therefore unique to Greenplan. The calculation of the fair cost share is as difficult as the vehicle routing problem itself. However, Greenplan has achieved to find a very precise calculation which is used later to define the cost complexity of a single parcel. This value is decisive for the parcel split between the two networks.

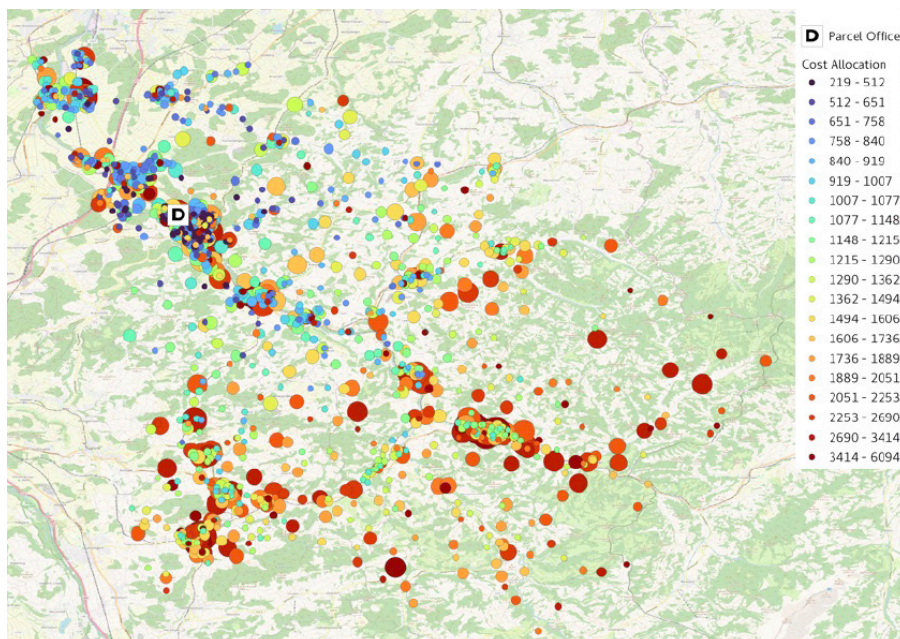


Excess values for each coalition (Excess = Cost advantage by allocated costs):

Coalitions	{a}	{b}	{c}	{d}	{e}	{a,b}	{c,d}	{d,e}	{c,e}	{c,d,e}
Left	0	1	0	4	2	0	2	2	0	0
Right	0.5	0.5	1	2.5	2.5	0	1.5	1	1.5	0

Left solution: Fulfills group rationality (No coalition pays more than on their own)

Right solution: Lexicographically maximizes excess values, leading to fair cost allocation



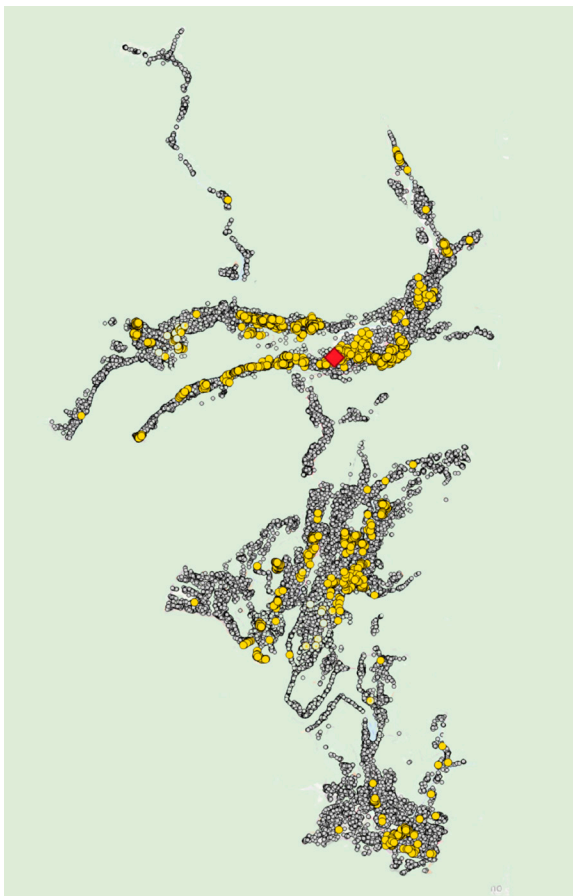
Size of bubbles =
time estimate

Color of bubbles =
expense of area group

3

DEFINE PARCEL SPLIT

Once we've determined the fair costs for parcels in each area, the next step is to decide whether parcels will be delivered through the combined network or the parcel-only network. This decision is based on the cost estimates we generated in the previous step. These cost estimates are now compared to the costs that would occur if parcels in a given area are delivered by the combined network. This delta in costs is the decisive value for the split of parcels being delivered by either of the two networks. By this method we assign these parcels to the parcel network which are not well suited for combined delivery, i.e. where the parcel network has a cost advantage. This might be due to shipments having very short time windows which would cause the costs in the combined network to rise.



Example:

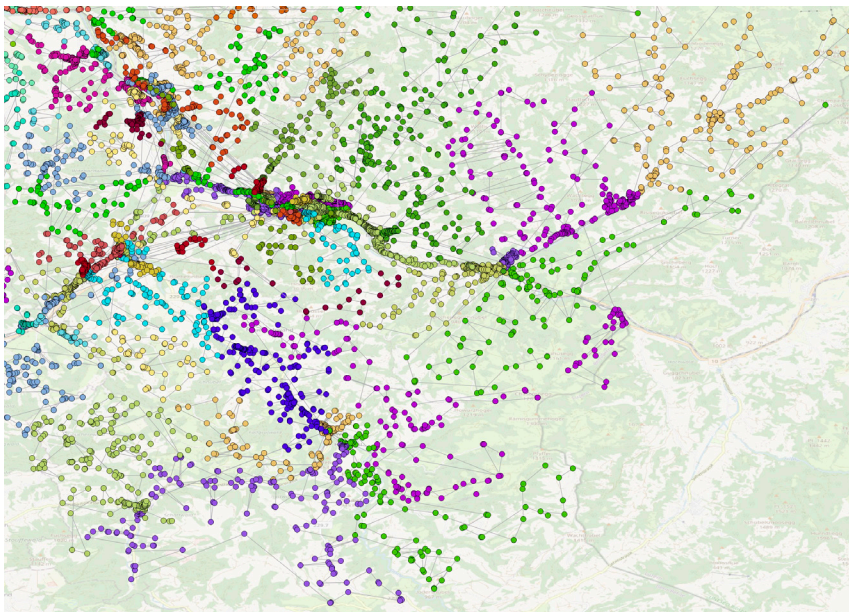
- ◆ Parcel delivery office
- Housekey served by parcel delivery
- Housekey served by combined delivery only

4

DESIGN SECTORS AND ROUTES

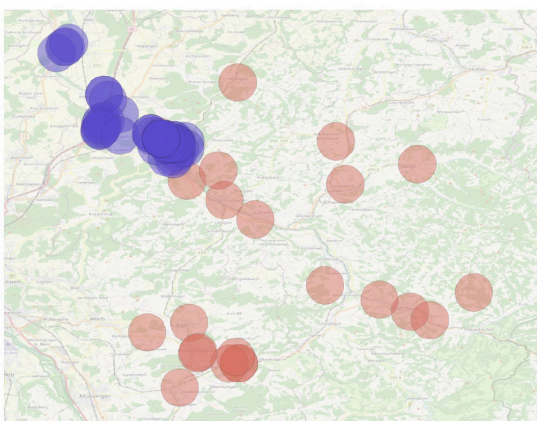
After we've decided by which network parcels will be delivered, we move on to designing the actual delivery routes. The delivery routes then ultimately define the boundaries of the sectors. In the sectorisation Green-plan can allow for fixed and dynamic routes. In the case of a postal company with the given two networks, it might be required to have a fixed stop sequence for the combined network, whereas the stop sequence for the parcel network may be dynamic. Thus, for combined sectors (letters and parcels), we can create fixed routes that drivers will follow each day. For parcel-only sectors, we can design more flexible routes that can change depending on the volume of parcels each day. This allows for more dynamic and efficient routing, especially during peak times when parcel volumes increase.

We also ensure that sectors are compact, meaning drivers spend less time on the road, and shipments are grouped as efficiently as possible.

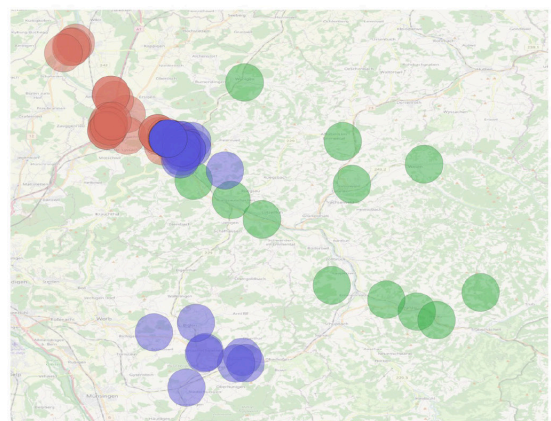


Example:

- Partition housekeys into combined delivery sectors (depicted with different colours, some colours repeat)
- Compute a static sequence in each sector for an entire 3-month period



Sector grouping optimized for low season



Sector grouping optimized for high season

5

EVALUATE THE RESULTS

Finally, we evaluate the performance of the routes and sectors we've created. This involves reviewing how well the routes are working in practice and making any adjustments needed to improve efficiency. We look at factors like delivery times, vehicle usage, and overall costs. If necessary, we adjust the routes or sector boundaries to further optimise performance.

WHAT IS A NUCLEOLUS AND WHY IS IT HAPPY?

The concept is called the "happy nucleolus" because it builds on the idea of maximizing the "happiness" of groups of participants, which is a term used in cooperative game theory.

Here's a simplified explanation:

- The nucleolus is a concept from game theory, specifically from cooperative games, where multiple participants (or players) work together and share costs. The nucleolus helps distribute costs fairly among the participants. It focuses on ensuring that the most "unhappy" group of participants (the one that feels the cost distribution is unfair) is as happy as possible. The goal is to minimize the dissatisfaction (or "unhappiness") of the most dissatisfied group.
- The "happy nucleolus" takes this a step further by trying to make as many groups as possible "happy". It calculates the cost each group would have to pay if they acted alone and compares it to the cost they pay when sharing with others. If a group is paying less in the shared setup than they would on their own, they are considered "happy".

By maximizing the happiness of all groups and ensuring that no group feels unfairly burdened by the cost, the "happy nucleolus" achieves a fair cost distribution, which is especially useful in logistics for allocating delivery costs in a balanced way across different regions.

3. ADDITIONAL SUCCESS FACTORS

3.1 HOMOGENEITY

Greenplan has worked with numerous clients and found that **HOMOGENEITY** is one of the major factors of designing sectors.

Greenplan focuses on ensuring that delivery sectors are similar in size and workload, which helps balance the time and effort needed across different delivery routes.

To achieve this, Greenplan uses methods like penalizing routes that are too spread out (i.e., covering too wide of an area) and balancing the working time across different routes. This ensures that no route is significantly more difficult or time-consuming than any other, making the overall operation more efficient and manageable.

3.2 CONTINUITY

Next to homogeneity, Greenplan has also found that **CONTINUITY** is a second major factor of designing sectors. Continuity is about keeping delivery routes as consistent as possible over time. This helps drivers become familiar with their routes, reducing errors and making deliveries faster. Greenplan ensures continuity

by encouraging similar routes in different iterations of planning. For example, assigning the same areas (delivery addresses/ housekeys) to the same routes whenever possible. This consistency not only makes operations smoother but also improves driver efficiency as they become more familiar with their delivery areas.

4. WHY GREENPLAN'S APPROACH WORKS

EFFICIENCY: By organizing delivery areas and routes in this way, we help reduce the number of vehicles on the road and the total distance driven. This saves fuel, reduces emissions, and lowers overall operational costs.

QUALITY: Our solution will be built to fulfil all quality constraints according to defined KPIs. The right trade-off between low costs and acceptable quality level has to be worked out in close collaboration with the postal provider.

FLEXIBILITY: Our system is designed to be flexible, allowing companies to adjust routes as parcel volumes change. This is especially useful for companies that experience seasonal spikes in deliveries.

BETTER SERVICE: With optimised routes and better cost management, companies can provide cost efficient and reliable deliveries, improving customer satisfaction.

5. WHAT MAKES GREENPLAN'S APPROACH GAME-CHANGING

With our new and innovative approach for sectorisation, Greenplan offers a more efficient, quality oriented, and flexible solution for modern logistics challenges, providing significant cost savings and improved operational quality.

We believe this approach to be game-changing for one distinctive reason: with the concept of "Happy nucleolus" calculating the fair cost share of single shipments the parcel split can be calculated to deliver the highest impact on cost reduction whilst maintaining quality up to the right level.

1

DYNAMIC ADAPTABILITY

Greenplan's algorithm is flexible, allowing delivery routes to change dynamically based on daily or seasonal parcel volumes. This flexibility helps logistics companies respond to fluctuating demands more effectively, improving efficiency during peak times without sacrificing service quality.

2

DATA-DRIVEN, PREDICTIVE PLANNING

Greenplan uses real-world data like traffic patterns and geographic constraints to build optimised routes. By considering factors like predicted traffic flow and road networks, Greenplan creates more precise delivery plans, which reduces driving time and fuel costs.

3

SCIENTIFIC VALIDATION AND PROVEN RESULTS

The algorithm behind Greenplan has been scientifically validated, showing an 8% cost advantage over traditional methods. This combination of cutting-edge research and practical application makes Greenplan's solution not only innovative but also highly effective.