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Fair Tour Planning: Managing Parcel Logistics by Neural Networks

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Abstract:

In times of high-frequency eCommerce, the value of parcel logistics grows continuously. Customers expect "sofortness" (instant delivery), which increases pressure on the whole delivery system. The ultimate performance driver is workforce. Teamwork is essential because only one conveyor belt exists to handle the whole process from collection to delivery; the "last mile" is the most complex part of the logistics process that must support fairness, rules, and compliance. We developed a platform to fulfill these requirements. An artificial neural network with deep learning characteristics builds clusters of logic and geographic segments. It helps to plan the delivery and to calculate the necessary performance per parcel and delivery stops. Daily controlling, automatic data preparation, and enrichment feed the artificial neural network. Finally, the application places segments sequentially to meet team fairness in a highly agile daily business of a logistics company in Luxemburg.

JEL Classification: L87, M54, O14, O15

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1 Introduction

1.1 Parcel Logistics

The German CEP market is determined by personal delivery, high speed (same day delivery), and small parcels lighter than 30 kg. In 2016, 3.16 billion shipments were sent in Germany and the CEP market employs ca. 219,400 people with an increasing tendency (BIEK 2017, p. 29); until 2020, an annual increase of 5.1% is expected (BIEK 2017, pp. 5). The services are essential for industry, retail and services to deliver in time with a guaranteed freshness. Especially what is known as the "last mile" gains importance. A decreasing number of potential employees follows recruiting problems. Urbanization, a growing number of elderly people, and singles challenge traditional logistic concepts (Urbanization is the expansion of cities by number, area and/or inhabitants (Bähr 2011, no p.). The number of shipments increased by 45% and the revenue by 39% which reflects a high pressure on markets and prices (BIEK 2017, p. 15).

We need to face the mentioned problems. The megatrends digitalization, convenience, ecology, and setting of standards gain ground (Pieringer 2017, no p.). But concepts are too abstract to solve real problems, especially the bottleneck of hiring qualified employees. Autonomous vehicles, drones, IoT are a vision, but need time for development and the process of regulations.

In our example distribution centre, our challenge today are 7,500 parcels that have to be delivered. This corresponds to about 5,000 delivery stops (an average of 1.5 parcels per delivery point), which are handled by drivers who deliver an average of 80 stops per day.

The calculation of the required workforce in this industry is based on the stop quantity of that day. More stops lead to more rounds. As a consequence, this leads to more spendings. But more parcels to the same location do not generate more costs in the delivery.

1.2 Human Values in Parcel Logistics

Digitalization will not only empower employees although it basically accelerates operational work, but monotonous work switches off brain functions due to the lack of variability of tasks and missing complex decision-making (Pinetzki 2012, pp. 16; Pickles 2016, no p.).

Digitally guided tour planning promises cognitive discharge, but even this will avoid complex decision-making on location. In worst cases, drivers must solve a conflict between the digital guide and different situations on site. When the digital system is always right, because it is a company's guideline, then it will prevent individual cognitive decision-making. Reducing the cognitive load will decrease awareness and therefore the understanding of the task and the driver's own role in the delivery system.

The human value, i.e. the value of the driver doing the job, is highly dependent on qualification, social skills, knowledge, and motivation. Therefore, non-monotonous work is a base for awareness and flexible use of the driver's cognitive system as well as motivation and positive emotions. Motivation relates to appreciation and fairness. Fairness in our article means equalizing the workload peaks in teams, considering process rules and compliance.

2 eBrahim: Fair Tour Planning Solution

2.1 Requirements

The first step is the definition of fairness among involved participants. To create a fair tour planning solution, we asked different supervisors about their basic understanding of fairness of the distribution. To aggregate this expert knowledge, we used a Fuzzy Cognitive Map (FCM), introduced by Bart Kosko (Kosko 1986), because these types of networks are a combination of fuzzy and neural logic that enable a seamless way from collecting expert statements and visualization up to computational simulation. FCMs are successfully used in labor productivity (see Ahn et. al. 2015) and logistic systems (see Bourgani et. al. 2014, Stylios et. al. 2011, Trappey et. al. 2009).

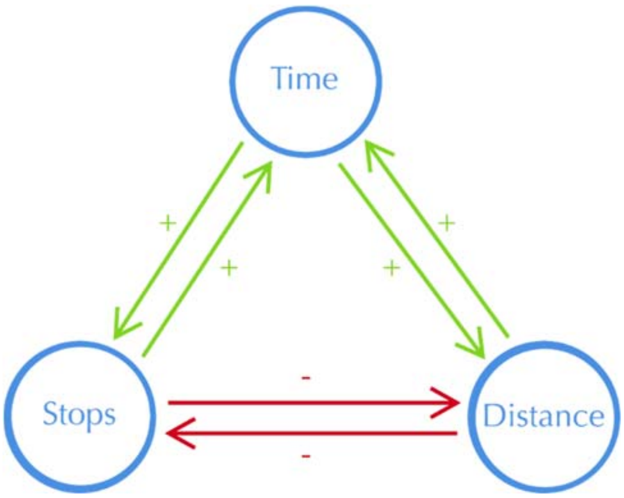

Figure 1: A simple FCM for fairness in parcel logistics

The result of our expert questionnaire is a simple FCM shown in Figureigure 1, representing the causal relations of fairness, distributing the parcels, and stops at a warehouse resp. a distribution center.

The FCM visualizes the main issues of fairness:

- "The more distance you drive, the fewer stops you can achieve."
- "The more stops you have, the shorter the distance you can drive."

- "The more time you have on the road, the more distance and/or more stops you can perform."

In practice, a good balance in the team that is on average 7 hours on the road for a long-distance tour is about 60 stops, while a city tour could be fine with 110 stops a day. Our goal is to have an equalized deviation of all delivery runs in the distribution center according to the FCM model.

Step 2 is a definition of clusters with minimum distribution area. They are determined by the limit of splitting an area into smaller parts, e.g. it doesn’t make sense to split a small village with just a few buildings into smaller parts. Clusters are the grey colored regions on the map of Luxemburg in Figure 2.

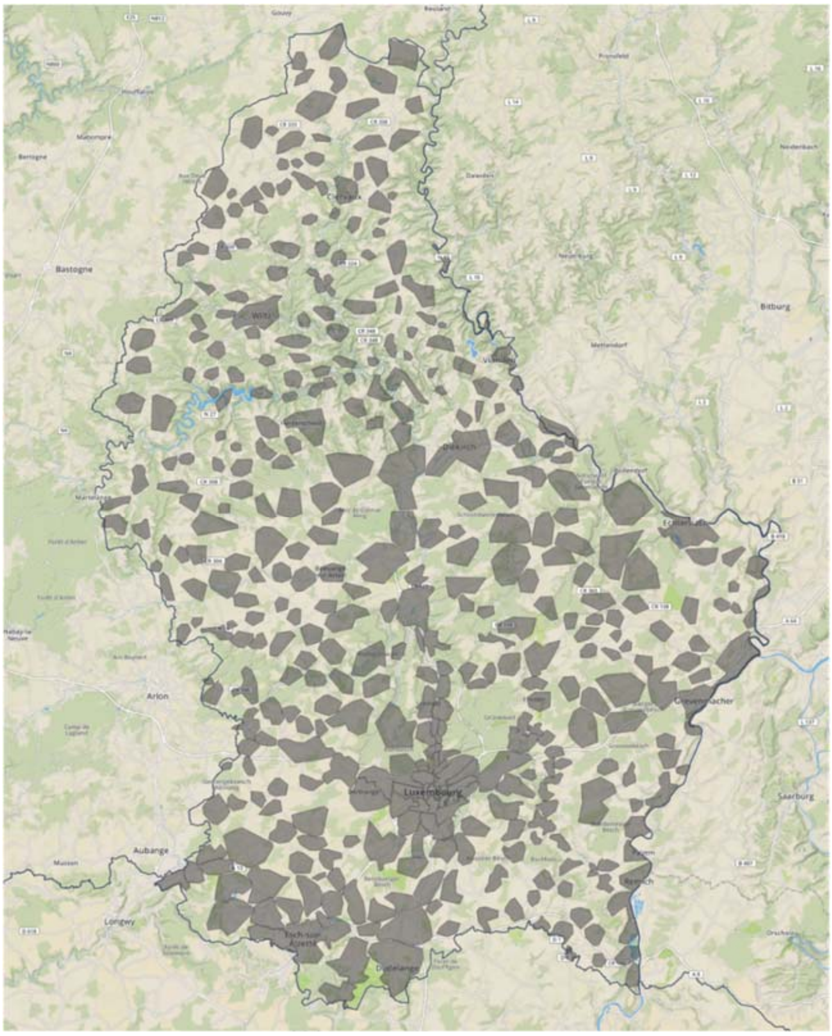

Figure 2: Defined clusters for Luxemburg

Step 3 is the collection of datasets with enough data. A large dataset of historical distribution data was required to calculate the density of stops in clusters for the first step of exploring the system’s behavior and quality. 1.56 million records were used for training and 4,000 per day for operational recall. Additionally, we used this information to validate the stops for possible manipulations of the delivery person.

2.2 The Artificial Neural Network

We used an artificial neural network (ANN) with the three layers input, hidden, and output (Figure 3). Initially, we took as input and output the three nodes of the FCM. However, we reduced the three input nodes to a single input node "density of stops" in a cluster and single output node "time" because today we only requested the time necessary for that stop amount. The hidden layer is a layer with 20 nodes, triggered by sigmoid functions. Our cost function is a mean squared error.

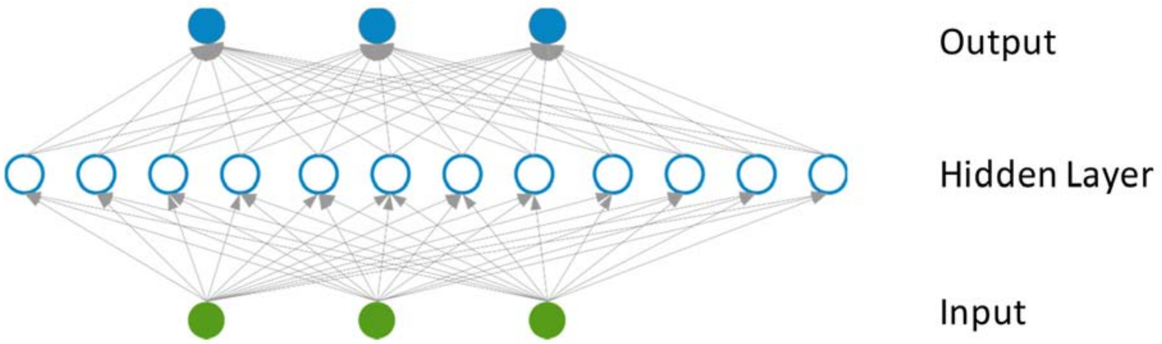

Figure 3: layer architecture of the artificial neural network

2.3 Making the Artificial Neural Network Work

The dataset for training the ANN requires the geo position of the stop (delivery point), the time between that single stops, and the information if the delivery is successful or not (is the customer at home?). Luckily, we used our individual platform that delivers enough data for training and testing. Crucial was the data cleansing and the proper preparation of data.

After short test runs, it became clear that the results had unexpected outliers. On closer inspection, the results showed that the detected stops were not always accurate. The spectrum of errors ranged from simple misrepresentations (e.g. wrong street names) to active manipulation (e.g. a driver sits in a café and enters data of long-delivered parcels). Therefore, we validated individual records intensively. We checked each delivery for plausibility and compared the last delivery and the next delivery.

We had to decide if eBrahim should be one ANN for all regions or a cluster of ANNs. In the latter case, the cluster times have to be aggregated. After some test runs, we found out that a cluster of ANNs needs less records for valid and accurate results. Finally, eBrahim works with 405 ANNs that represent each cluster and the answer to our question "How long does one tour take?" can be found by a simple addition of single clusters.

2.4 Requesting a Dispatch for Today

To calculate a proper dispatch, we must know what is actually in the pipeline. This is harder to achieve than initially thought because shippers who do not register their packages are not rejected by the delivery staff. The focus is on the service to the customer and therefore the parcels are first delivered and added to the global database while delivery and invoiced parcels afterwards. This causes a "physical before logical" phenomenon: the parcel is faster than the data.

To avoid this obstacle, we captured all parcels and activated them while entering the distribution center (entry scan). Parcels whose data has now been transmitted by the sender are assigned directly to the clusters. However, there are still packages for which we have no information, but we recorded all to allow for accurate planning.

Despite activation, some packages will not contain any information at the time of goods receipt because not every sender will have the data transmitted until delivery. For these packages, we must enrich the data.

2.5 eBrahim Components

eBrahim's data is captured by a variety of interfaces. The packages are activated by the entry scan with a scanner app, enriched by a back office software (add more data to a parcel manually), and assigned by eBrahim to the tours (eBrahim is a cluster server with a web interface). When loading the vehicles, a splitter app helps to sort the packages into individual vehicles and shelf positions. A dispatcher app and a driver app complete the range of applications to serve the users at the point of decision.

The **scanner app** supports the registration of all parcels in the depot. All data of the daily planning are collected simultaneously. The collaboration of all apps, tools and people is mandatory for the eBrahim and it's ability fot a qualified planning. All parcels without adress and service information must be re-recorded.

Our back office tool "**Zengi**"–it comes from the Turkish word "Zenginleştirme" which means enrichment–supports the completion of data and delivers them to eBrahim (Figure 4).

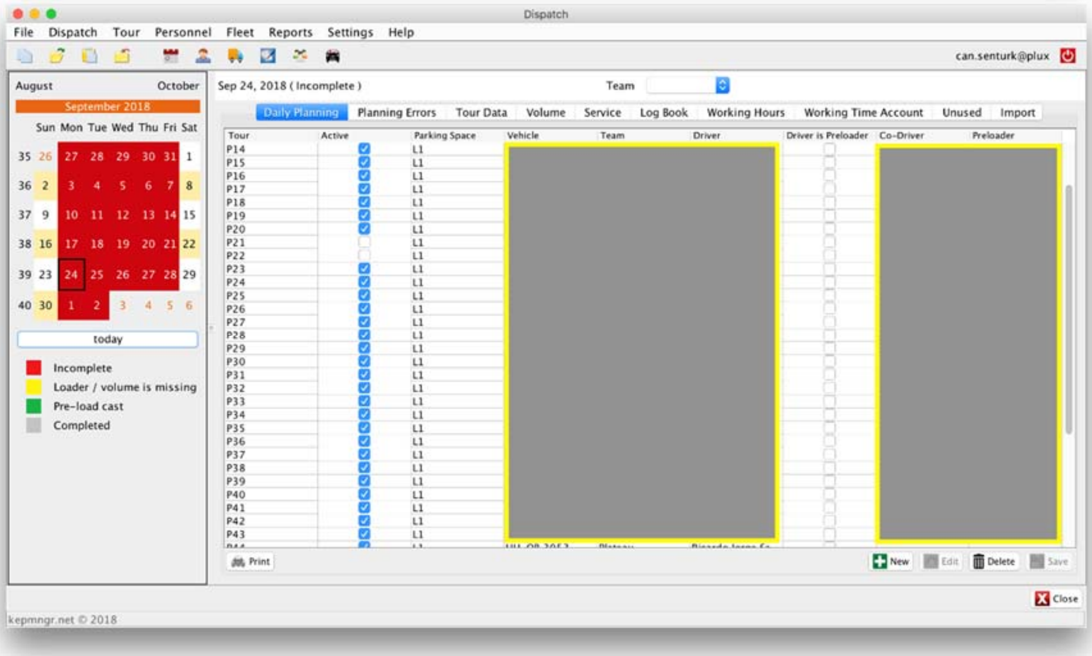

Figure 4: The interface of Zengi

The **splitter app** identifies the direct tour to which this package is assigned for each package (Figure 5). This simplifies the sorting of the packages enormously since, at any time, the internal warehouse routing is fixed and untrained personnel are directly capable of action. But also territorial disputes among the drivers are thereby avoided. In case of discrepancy, the management is consulted. Disagreements and disputes among drivers do not arise in the first place. A rescheduling of tours is immediately available to all through the splitter app.

Figure 5: The interface of the splitter app

The **dispatcher app** is the command center for daily planning to check the current tour overview (Figure 6). eBrahim's suggestions can be activated, revised, or your own plans can be implemented here directly. Moving a cluster from one tour to another is possible here as well as creating or cancelling a whole tour.

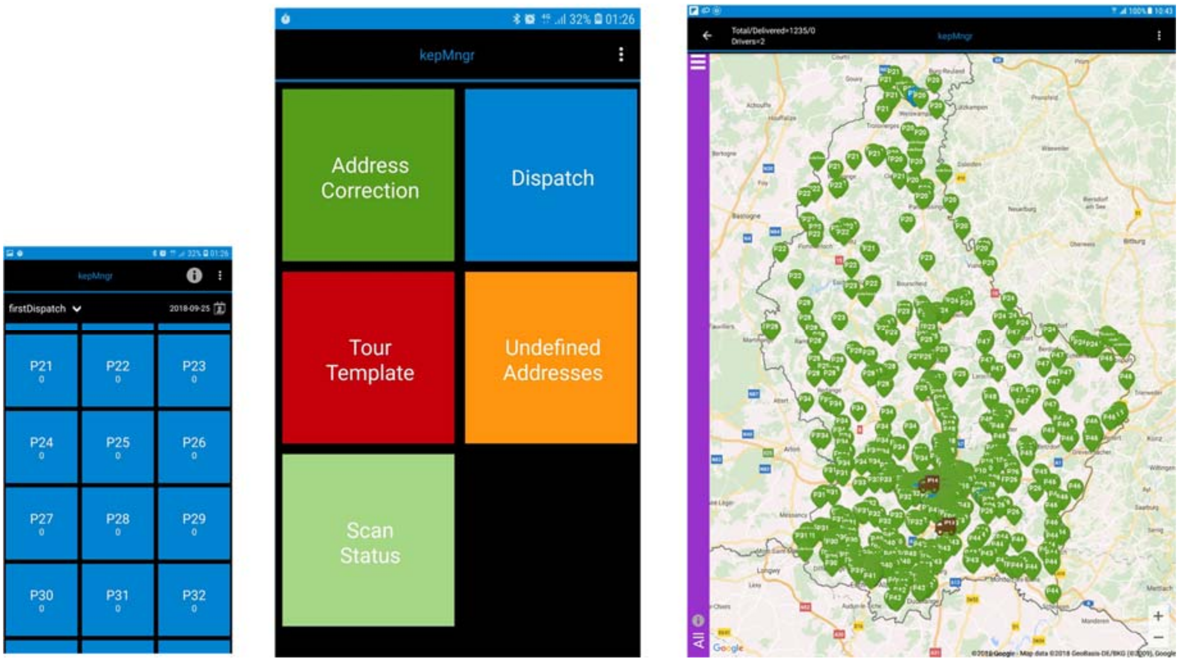

Figure 6: The interface of the dispatcher app

The **eBrahim web interface** is used for the optical visualization of the clusters' utilization (see Figure 8), but also for the rearrangement or assignment of the clusters to tours.

As a result, the single tour working hours can be estimated in advance. The driver and the manager have a valid, reliable, and objective system to predict the working hour of that tour, measured on the only scale that is fair: working time.

Finally, with this method the total performance of a day is distributed fairly throughout the team by similar working hours for everybody.

eBrahim's cluster server is fed by real historical data of the delivery. However, eBrahim must be able to adapt to structural changes in areas and/or habits of clients. To accomplish this, the neural network is trained again, including the new data from the previous day. This ensures the timeliness that is essential in this fast-growing sector.

The **driver app** allows to enter the parcel's delivery status and visualizes the driver's position as well the client locations (Figure 7).

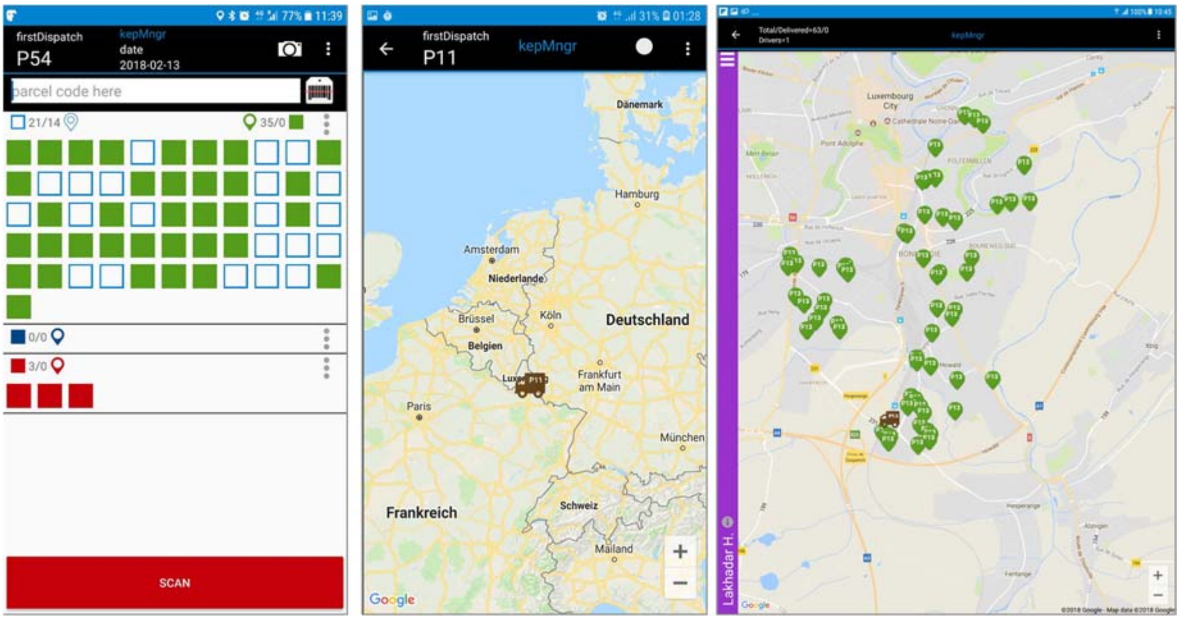

Figure 7: The interface of the driver app

3 Results and Outlook

The heat map is an estimation of the daily delivery time per cluster. By selecting multiple clusters, you can easily arrange the desired working time (Figure 8).

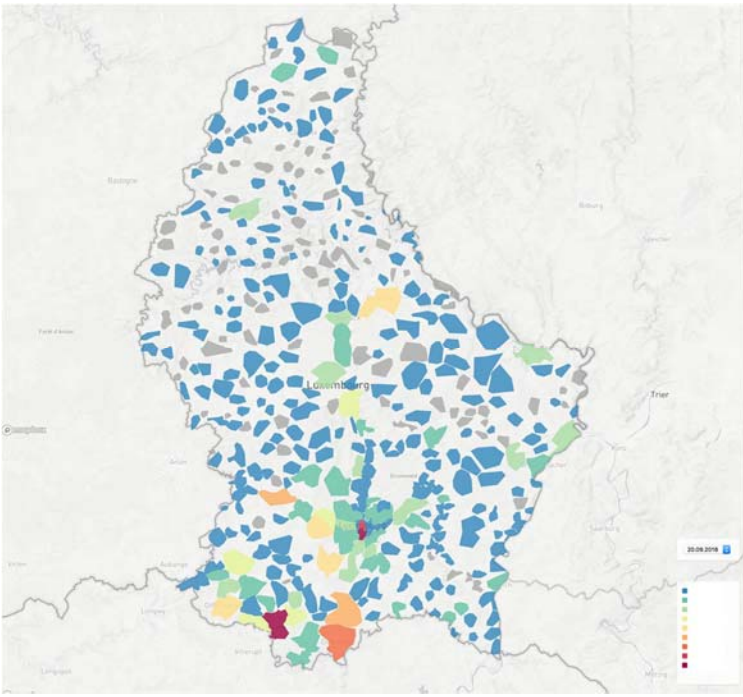

Figure 8: A heat map generated by eBrahim

Is eBrahim stable in daily work and did we reach our target of fair planning? eBrahim, like a biological intelligence, is totally dependent on the sensorial elements for its effective usage. Since January 2019, eBrahim is productive in daily planning. But we need to increase the reliablity of all sensors (scanners, Zengi, Driver App, Dispatcher App) to a maximum. We need a 99.99% reliablity (and more) to increase the trustworthiness of the people to a software system. Finally, we equalized the workload peaks and established more fairness in our driver teams.

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