CLOUDLOGISTIC - A FORMAL DESCRIPTION OF EXCLUSIVE FREIGHT ROUTES BASED ON A MULTI-ZONE MODEL WITH ELLIPTIC ISOCHRONES

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ABSTRACT

Based on previous works this paper introduces a formal description of exclusive defined freight routes using a multi-zone approach to define source and target areas as elliptic isochrones. This work contributes to publications in context of the so-called "CloudLogistic" concept. As an innovative approach to strengthen the market position of Small and Medium-sized Enterprises (SME) and to increase their efficiency, the CloudLogistic concept aims for building a novel kind of freight cooperation in the area of Less than Truck Load (LTL) transports.
The use of a multi-zone model enables the freight cooperation to maximize its efficiency, to implement innovative pricing strategies and to create individual unique selling features for each single Logistic Service Provider (LSP). By using an elliptic definition with geographical focal points for these zones a more flexible definition of source and target areas is realized. To reduce geographical impacts a time-based distance-function is used.
The presented design of the exclusiveness of freight routes by defining monopoles via so-called core-areas is a useful approach to deal between the individual requirements respectively intentions of each single LSP and the attainment of global goals of the whole collective network structure.

Keywords: CloudLogistic, SME, LSP, Freight Routes, Exclusiveness, Elliptic Isochrones

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INTRODUCTION

The Federal Ministry for Transport, Building and Urban Development (BMVBS) forecasts a substantial growth of the traffic volume in road haulage up to the year 2025.[2] Especially the long-haul road transportation contributes to this trend. A growth of transport volume of about 55% and an increase in traffic of about 84% is expected. From the ecological and the economic point of view, these trends should not only be faced with an adjustment of the road network, but also with a more efficient use of the existing infrastructure.[3] In Germany, every fifth truck in commercial freight traffic is already driving without any load at all.[4]

The so-called "CloudLogistic"' concept addresses these challenges and represents an innovative concept for freight cooperation to strengthen the market position of Small and Medium-sized Enterprises (SME) in the long-haul road transportation. The concept transfers the strengths of already existing general cargo and Full Truck Load (FTL) networks to the area of Less than Truck Load (LTL) transports. Mentioned by Bretzke[5], CloudLogistic addresses the requirements for a promising, most likely successful cooperation model of a horizontal transport network for LTL. Bretzke aims for a fundamental decoupling from the customer. This means that all shipments have to be distributed centralized and globally optimized to the network LSPs – regardless of which LSP has given the job.

Usually it is not possible for a Small and Medium-sized Logistic Service Provider (LSP), to transport several LTL shipments together in one truck because there are not enough shipments within similar source and target areas. Hence, for a single LSP, several trucks are required for the transport of several LTL shipments. The CloudLogistic concept bundles LTL shipments of several cooperating LSP, via a cooperation network by combining corresponding LTL shipments to generate synergetic effects. Thereby, the concept relies on a line-based logistics model. The economic pressure[6] has risen due to the introduction of transporter tolls. This economic burden is noticed especially when dealing with LTL. Small and medium-sized LSP's have to cooperate with each other in order to fight against this strain.[7]

Similar to the IT term "Cloud Computing", the "CloudLogistic" concept describes the ability and opportunity of the LSP's to share unused resources by participating in a freight cooperation network. This is done by using its infrastructure, its resources and scaling them locally while even sharing their own infrastructure and resources with the network. Several shipments of different network-partners will initially be bundled and assigned to previously established freight routes. Each route is operated by a partner of the cooperation. For a combined disposition of LTL shipments, freight routes are established, i. e. the relation

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[2] *see Bundesministerium für Verkehr, Bau und Stadtentwicklung (2007)*

[3] *see Bundesministerium für Verkehr, Bau und Stadtentwicklung (2008)*

[4] *see Helmreich, Keller (2011)*

[5] *see Bretzke (2010)*

[6] *see Hauert (2008)*

[7] *see Friedrichsmeier et al. (2012)*

between a source and a target area that is operated regularly by several trucks via point-to-point transportation.[8]

With backing evidence from previous papers, this paper describes the spatial fundament of the CloudLogistic concept. This paper specifically addresses the *formal* description of the source and target areas of freight routes as elliptical isochronal multizone-areas and introduces the term of the core area and the exclusiveness of a freight route. After the brief introduction of the CloudLogistic concept in paragraph 2, the formal model of the freight routes are precisely described in paragraph 3. Subsequently, the exclusiveness of a freight route for a particular LSP will be introduced in paragraph 4. In paragraph 5, in connection with the conclusion, the motivation for future works is given.

AN ELLIPTIC MULTIZONE-MODEL

The foundation for the formal description of freight routes is the formal description of their implied source and target areas. Shipments whose origins are within the source area of a freight route and if the destination is in its target area, the shipment can be sent off in the corresponding direct transport (see Figure 1).

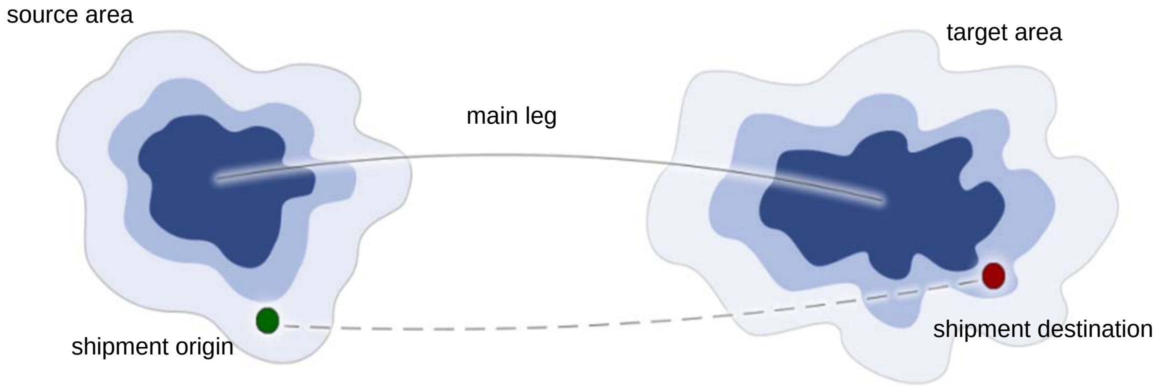

Figure 1: source and target area of a freight route and its main leg

Source and target areas are consequently bordered within a specific geographical space. This space is individually set depending on the freight route. In order to reach the necessary national wide coverage and to create optimization potentials which exceed the immanent usage of synergies, it is necessary to create possibilities for the overlapping of source and target areas within different freight routes. The corresponding optimization problem was subject of earlier work.[9]

The cooperation which is considered as the superordinate entity, strives for maximum national coverage and optimization potentials for the collective. Contrary to this, the

[8] *see Tummel et al. (2012)*

[9] *see Tummel et al. (2011)*

individual LSP's strive for its own personal interests. Consideration in describing the freight routes is necessary, especially when reaching a unique selling point in the form of exclusive operations of different freight regions and its source and target areas (see Paragraph 4).

In order to define the terms source area respectively target area and finally freight route, the term of the geocoordiante is introduced. The definition is according to previous works. [10] [11]

Definition 1: geographic location / set of all geographic locations
Let $\lambda \in \mathbb{R}$ be the longitude $-180° \leq \lambda \leq 180°$ and $\varphi \in \mathbb{R}$ the latitude $-90° \leq \varphi \leq 90$ then the ordered pair $A = \langle \lambda, \varphi \rangle$ is called geographic location. Let $\mathbb{W}$ denote the set of all geographic locations.

The source area of a freight route is defined via multiple zones and via two spatial geographic locations; A and B (see Figure 2). The geographic location A represents the geographical location of the depot respectively LSP and declares a surrounding area. With geocoordiante B the area can be optionally spanned and adjusted. Choosing a geographic location B is done in consideration of the specific geographic characteristics of a particular depot and in accordance with the LSP.

A source area is not only defined through its core-area but also through multiple expansion zones. In particular the individual freight charge and the probability of the shipment being sent on a particular freight route are based on such zones. LSP are compensated higher when the freight is shipped to a farther zone. It is also the goal of the cooperation to allow a most ecological assignment of the cargo on a particular freight route, while meeting the economic variables, from the perspective of the superordinate simultaneously. Therefore, the allocation of a shipment to a particular freight route is more probable when origin and destination of a shipment are in or nearby a core area.

For the foundation for the description of such zones, a time-based approach was chosen which considered the available road networks. In order to estimate the relevant distances a truck-based routing planer is used. These should be able to calculate the distances for geographic locations which are not directly part of the road network and otherwise would have to be estimated.

According to definition 1, the general underlying distance function will be introduced considering the metric triangle inequality. Specifically the distance function in the CloudLogistic concept takes shape as a time-based distance function, considering the road network. Hence the set of two geographic locations; A, B is assigned to the time value which requires a truck to drive from A to B using the road network.

[10] *see Tummel et al. (2011)*

[11] *see Tummel et al. (2013)*

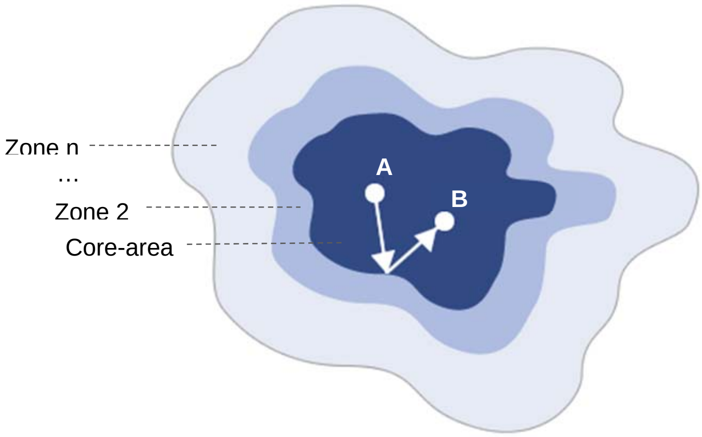

Figure 2: general scheme of area as elliptical multi-zone model

Definition 2: distance function
A function $d: \mathbb{W} \times \mathbb{W} \rightarrow \mathbb{R}$ is called *<u>distance function</u>, if for any geographic locations $A \neq B \neq C \in W$ the following conditions hold:*

- $d(A,B) \geq 0$ *(The distance is always positive)*
- $d(A,B) = 0 \Leftrightarrow A = B$ *(A location only has a distance of zero to itself)*
- $d(A,B) \leq d(A,C) + d(C,B)$ *(A detour via location C must not decrease the distance).*

Using definition 2, the formal description of source and target areas will be introduced as an abstract area description. First the general area without zone division is defined. The definition is based on the "Pins-and-String Method" (Gardner's Ellipse)[12] which describes elliptical geometries.

Definition 3: (source- and target-) area / focal points
Let $A, B \in \mathbb{W}$ be two geographic locations, $\bar{r} \in \mathbb{R}$ a real number and $d: \mathbb{W} \times \mathbb{W} \rightarrow \mathbb{R}$ a distance function. Then the set:

$$G_{A,B,\bar{r},d} = \{X \in \mathbb{W} | d(A,X) + d(X,B) \leq \bar{r}\} \subset \mathbb{W}$$

is called <u>area</u>. In this case A, B are called <u>focal points</u> of this area.

If the time-based distance function $\mathrm{d_t}$ is chosen, the geographical area $\mathrm{G}_{\mathrm{A,B,\bar{r},d_t}}$ is defined as an elliptical isochrone. The definition above will now be extended into the already motivated multi-zone approach.

Definition 4: multi-zone area / set of all areas
Let $G_{A,B,\bar{r},d}$ be an area. Further let $Z = \{z_1, z_2, \ldots, z_n\} \subset \mathbb{R}$ be a set of different distances with $0 < z_1 < z_2 < \cdots < z_n = \bar{r}$ and $n > 1$. Then the set $G_{A,B,\bar{r},d,Z}$ is called <u>multi-zone area</u> and $\mathbb{G}$ denotes the <u>set of all areas</u>.

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[12] *see Zieschang (1997)*

If location B of a source area is not given, all locations are within one zone which can be reached within a maximum time-frame from the depot A. The needed time to collect the shipment at its origin – basically the route from depot to origin and back again – is in this case limited to 40 minutes. By specifying location B the area will be adjusted in an elliptic way. Such kind of area describes all geographic locations which are part of a turn from A to B (including the detour). This turn is limited to a time-frame of 40 minutes. The target area of a freight route is defined analogically.

Geographically speaking, the shape of a defined area significantly varies with the choice of a specific distance function. The choice of the Euclidean distance of two graphical locations describes a completely different geographical area as if the choice were – like in the case of the CloudLogistic concept – a time-based distance function. The choice of source area and target area is defined in connection with the acquirement of a so-called freight concession. This decision would of course be reached in coordination with the cooperation. The variables A, B and their respective zones are assigned to individual source and target areas. As seen as part of the model, many time-zones can be indicated.

A FREIGHT ROUTE WITH ITS SCHEDULE

Before introducing the term *freight route* formally, the terms *resource* and *schedule* has to be defined first. In this model only the *truck* on an LSP is taken into account for defining the resource. As the LSP only is responsible for providing the needed human resources, the consideration especially of the truck driver is not part of this model. The given schedule with its related resources is implying the human resources sufficiently.

The schedule describes in the form of a timetable the day of dispatch, the day of delivery and the specific resources, which are provided to serve the related source and target areas (see Figure 3).

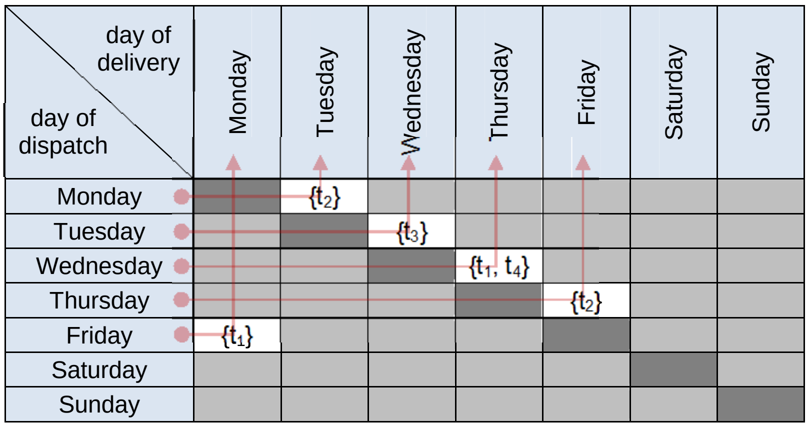

Figure 3: Example of a schedule of a freight route with day of dispatch, day of delivery and the specific resources $\{t_1, t_2, t_3, t_4\}$.

The given example describes the schedule of a freight route of an LSP which serves a relation between a source and a target area from Monday to Tuesday, from Wednesday to Thursday, from Thursday to Friday and from Friday to Monday with only one truck. The main leg from Tuesday to Wednesday is served by an additional truck.
The following definition is not restricted to a period of a week, but it is based on the specific working days.

Definition 5: trucks / schedule of a freight route / resource
Let $\mathbb{T}$ be the set of all trucks of a LSP. Furthermore let $\mathbb{D}$ be the set of all working days, $i \in \mathbb{D}$ the day of dispatch and $j \in \mathbb{D}$ the day of delivery.
Then f denotes the schedule of a freight route with:

$$f : \mathbb{D} \times \mathbb{D} \longrightarrow Pot(\mathbb{T}), \langle i, j \rangle \mapsto T$$

as map from the pair $i \in \mathbb{D}$ (day of dispatch) and $j \in \mathbb{D}$ (day of delivery) in a set of trucks $T \in Pot(\mathbb{T})$. Then each truck $t \in T$ is called resource for day of dispatch i to day of delivery j.

At this moment a more detailed definition is not needed. It is sufficient to say that resources of freight routes (so the implied trucks) are specified with a lot of different characteristics (i. e. the available loading meter, the payload limit, lifting platform, COIL-device). Which parameters are needed depends on the specific application and the optimization case.
Based on the definitions above, now the freight route has to be formally defined as the union of source and target areas, its implied main leg and the resources which has been allocated in the schedule.

If the shipments origin is part of a freight routes source area and its destination is part of the corresponding target area, the shipment will be assigned to this freight route (see Figure 1). If there is more than one fitting freight route, the decision depends on several factors (i. e. fairness factors, economic aspects) which are needed to reach the specific optimization goals. For more information the reader may refer to earlier works[13].

Definition 6: freight route / set of all freight routes / core-area
Let $G^s \in \mathbb{G}$ be a source area and $G^t \in \mathbb{G}$ be a target area. Furthermore let f be a schedule of trucks $\mathbb{T}$ of an LSP. Then the tuple $l = \langle G^s, G^t, f \rangle$ is called freight route and $\mathbb{L}$ denotes the set of all freight routes.

Then the area $G_{A,B,z_1,d,\{z_1\}} \subset G_{A,B,\bar{r},d,\{z_1,z_2,\dots z_n\}} = G^s$ is called source core-area of freight route l and the area $G_{C,D,z_1,d,\{z_1{}'\}} \subset G_{C,D,\bar{r}',d,\{z_1{}',z_2{}',\dots z_n{}'\}} = G^t$ target core-area of freight route l.

[13] *see Tummel et al. (2013)*

EXCLUSIVE FREIGHT ROUTES

By acquiring a so-called *freight route concession* the *concessionaire* obtains special rights to serve the defined source and the target areas exclusively. These exclusive rights are specified by the terms *source area monopoly* and *target area monopoly* (see Figure 4 and Figure 5).

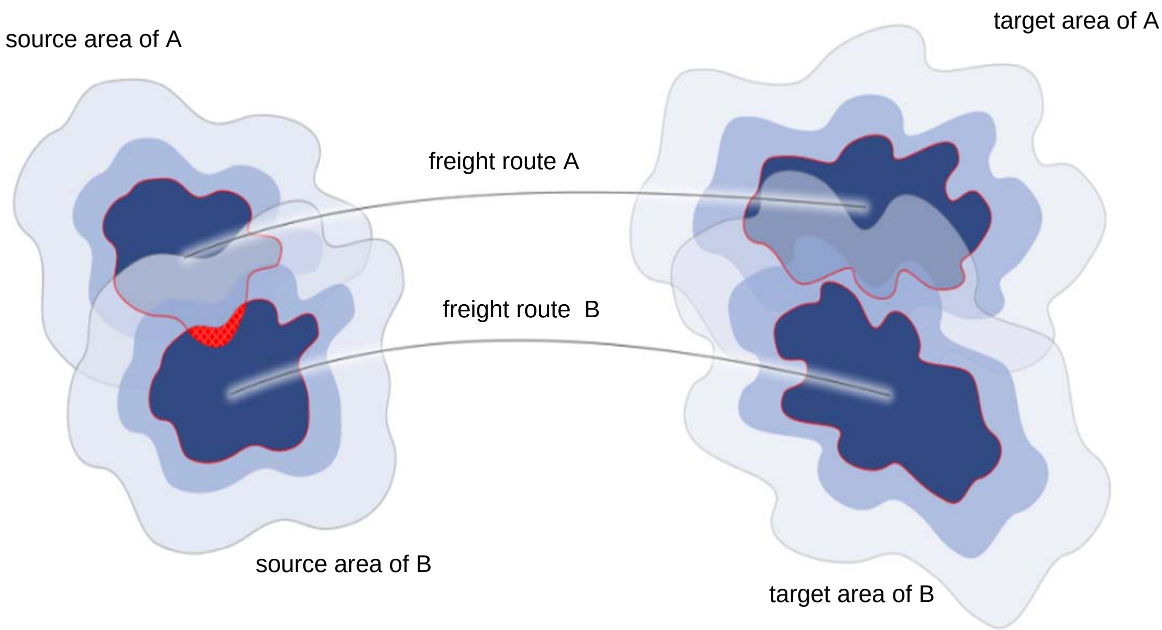

Figure 4: Example of a valid concession contracting by observing the source area monopoly

The specific source core-areas of two different freight routes may overlap each other, if the related target core-areas do not overlap each other (*source area monopoly*). The specific target core-areas of two different freight routes may overlap each other, if the related source core-areas do not overlap each other (*target area monopoly*).

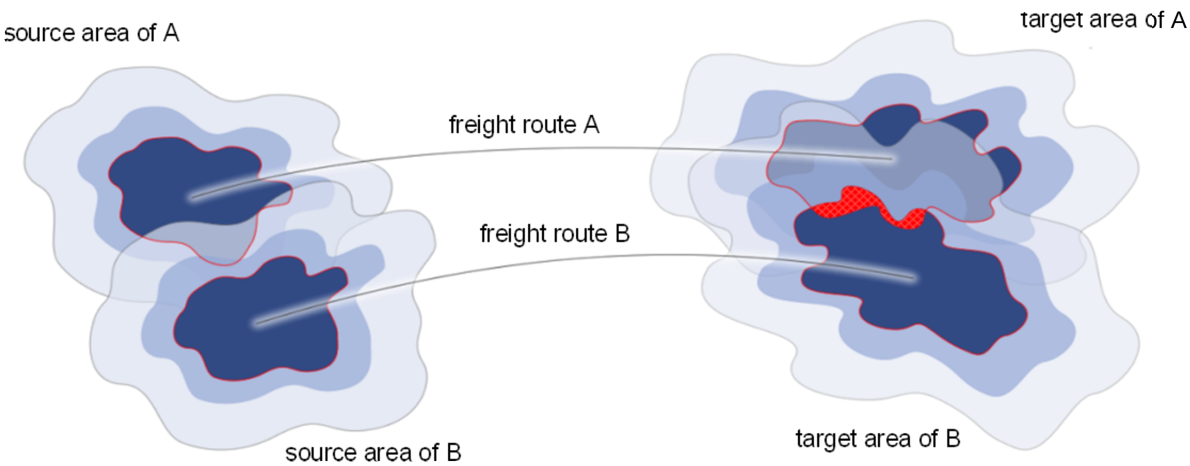

Figure 5: Example of a valid concession contracting by observing the target area monopoly

In this context a freight route is called exclusive, if on the one hand the source area monopoly and on the other hand the target area monopoly constraints hold. This means after a freight route concession is granted, the core-areas of later acquired freight routes may not overlap both core-areas of the existing freight route concession. A formally description of source and target area monopoly and the exclusiveness of a freight router is given in Definition 7.

Definition 7: source & target area monopoly / exclusiveness of a freight route

Let $G_l^s \in \mathbb{G}$ be the source area and let $G_l^t \in \mathbb{G}$ be the target area of a freight route $l \in L$. Furthermore let $G_l^{sc} \subset G_l^s$ be the source core-area and $G_l^{tc} \subset G_l^t$ the target core-area of l.

For l a source area monopoly is given if:
$\nexists x \in L$ *with* $l \neq x$ *with source core-area* G_x^{sc} *with* $G_x^{sc} \cap G_l^{sc} \neq \emptyset$.

Analogous a target area monopoly is given if:
$\nexists x \in L$ *with* $l \neq x$ *with target core-area* G_x^{tc} *with* $G_x^{tc} \cap G_l^{tc} \neq \emptyset$.

A freight route l will be denoted as exclusive, if:
$\nexists x \in L$ *with* $l \neq x$ *with source core-area* G_x^{sc} *and target core-area* G_x^{tc}
with $G_x^{sc} \cap G_l^{sc} \neq \emptyset \wedge G_x^{tc} \cap G_l^{tc} \neq \emptyset$.

On the one hand this definition observes the requirements of the LSPs to establish individual exclusive territories and the related territorial unique selling feature for each LSP. To reach the needed domestic coverage and to create potentials to optimize the global assignment scenario by aiming different optimization goals for the collective, the exclusiveness of a freight route is restricted to the specific core-areas on the other hand. The contracting of such kind of concessions has to observe these given guidelines. Nevertheless for reaching a high domestic coverage the contracting is not able to guarantee the observance of this guideline. Therefore the following extension is given: In case of competing the earlier contracted freight route will be favored.

CONCLUSION AND OUTLOOK

The presented formal model forms the basis for the development of the related centralized software-based service, which is needed to realize the CloudLogistic concept. On the one hand the introduced multi-zone model with elliptic isochrones combines the requirements of medium-sized LSPs to a time-based description of source and target areas with the opportunity to adjust them geographically by choosing two focal points. On the other hand creating overlapping areas enables the chance to reach a domestic coverage and it creates potentials to optimize globally by aiming for goals which improve the collective. Respecting the requests of the LSP to create an individual unique selling the exclusiveness of a freight route according to their specific core-areas has been integrated in the model description.

Furthermore the presented model is the base of the related pricing model, which is geared to the multi-zone description of freight routes. Also the related optimization process uses this definition to minimize the distances between origins and source core-areas respectively destinations and target core-areas by choosing the specific freight route. Based on this model the further work aims for the development of a problem-specific optimization procedure (i. e. by using evolutionary algorithms) and the evaluation of the operative assignment planning. Further methods for optimizing the whole network from a strategically and tactical point of view is supposed.

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