Approach to simulations of goods deliveries with the use of Cargo Bicycles

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Abstract. The loading points (Cyclelogistics Micro Hub, Urban Consolidation Centre, Urban Satellite Platform or Pick-up Point) are an indispensable element of cargo bikes transport system. The choice of location of those points is a basic issue to be solved in designing distribution systems for goods. The paper describes the approach to justifying of the location of loading points, based on the computer simulations of the cargo delivery process using cargo bikes. An implementation of the distribution system model was created with using the Python programming language. The use of software allows to perform simulation experiments for various variants of location of loading points and more.

AREA OF THE RESEARCH

Effective transport of loads within cities is a highly problematic issue and generates relatively high costs in relation to the entire delivery process. Neglected by executive units and researchers, the subject causes its practical aspect to be faced with numerous physical, administrative and organizational limitations. In addition, the delivery of the last kilometer (last mile) is usually characterized by a large diversity of loads (in terms of natural susceptibility) and low utilization of the transport means. That is why distribution systems of goods based on cargo bikes, which are part of the trend known as “cyclelogistics”, deserve for special attention.

However bicycles have weaknesses, for example: shorter (than the car) maximum distance of delivery. Therefore, when a system works on a large area, it is necessary to use a loading point (one or several). It makes that the distance of delivery by the bicycle is shorten. Loading point (Urban Consolidation Centre e.t.c) can be: trailer or semi-trailer, container cargo unit - as examples of a mobile loading points; dedicated transshipment bay, "parcel locker", storage room - as examples of permanent loading points. In science there are methods of solving the problem of location of loading points, however they are often ineffective in practice because they do not take into account the set of possible locations. That is the reason why, to make a useful of the simulation results in practice, it seems reasonable to include a set of possible locations of loading points due to the special terrain conditions of the system environment

MATHEMATICAL MODEL

As a starting point for creating a mathematical model of a cargo distribution system, is the identification of its elements. We can list the following subsystems of whole distribution system:

- transport network - under which the freight transport process is carried out;
- demand for the supply of goods - reflecting the client’s demand for the carriage of cargoes;
- subsystem serving a demand for a supply of goods - containing means of transport (cargo bicycles) and loading points.

The most commonly used approach to modeling transport networks is a use of mathematical structures based on graph models. In the mathematical model, as the node of the transport network, we will present customers (for

which the loads are delivered), while the links will reflect the relevant sections of the road network – connection of the customers. In addition, the loading point, from which the loads are exported by bicycles, can be represented as the node of the network.

The basic variable shaping the demand is a request for a delivery of goods, understood as the customer's demand for services. Each request can be quantified with a set of numerical parameters, among which the most significant are: the size of the load unit, its dimensions, time interval between requests, and the distance of delivery. In the general form, a demand model can be presented as an orderly (by the time) set of requests. Because of that, the task of a demand modeling can be presented as a task to generate a queue of requests with random parameters.

The elements of the servicing system are: a fleet of transport means (cargo bikes) and loading points. The main parameters of cargo bikes as elements of the servicing system are: load capacity, dimensions of cargo space and technical speed. Moreover as a loading points we mean short-term (temporary) storage points, to which cargo is transported by other means of transport (mostly vans), for deliver them to the final customer. The main parameters of loading points are: their location and capacity.

SOFTWARE IMPLEMENTATION

The library of basic classes was created with the Python programming language. Each class has the necessary parameters describing the mathematical model of a distribution system. Additionally, the "Net" class contains a method for generating demand as a flow of the requests with random variables of numerical parameters for each consignment, methods for calculating the shortest distance matrix based on the Floyd-Warshal algorithm and a method for shaping delivery routes implementing Clark-Wright algorithm. Therefore simulation experiments which determine which from possible locations is the best according to the previously established criterion, are possible to run. The general structure of the library is shown in Fig. 1.

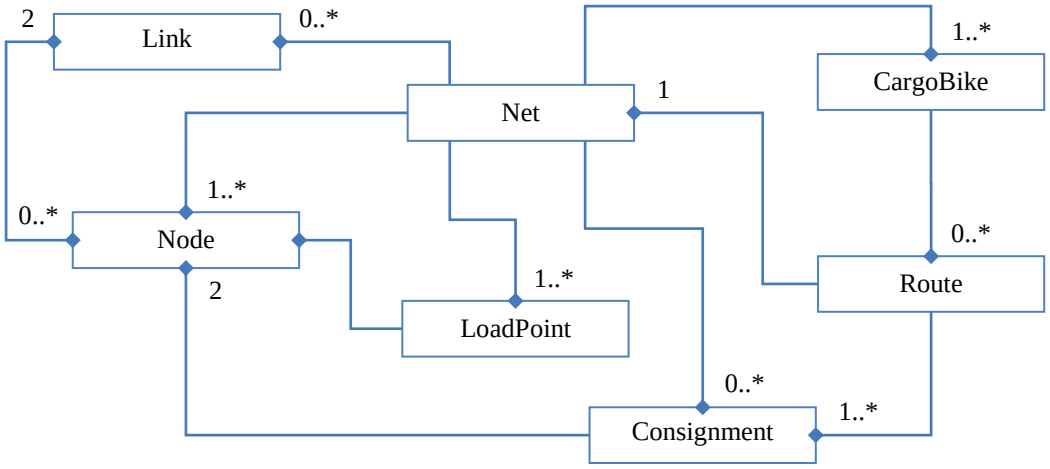

FIGURE 1. UML diagram of the class library for modeling a bicycle delivery system

SOFTWARE CAPABILITIES

The created software allows to choose the best variant of a loading point's location from the set of possible locations. However after a little modification, it can be used for a extensive applications. For example: it can be used to justify a capacity of means of transport (not only freight bikes but also electric cars etc.). In addition, this tool can be helpful in fleet management justifying number and type of vehicles in a transport system. It can also be used to rationalize existing cargo delivery systems and be a helpful tool for their design. There can be much more similar examples of applications in logistics.