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Analysis of Possibilities of Integrating Cargo Bikes into Urban Space

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Abstract

The paper analyses current various ways of use cargo bikes and defines the resulting demands on urban planning. Although the infrastructure for cycling has been developing succesfully in recent years, the existing infrastructure does not always meet the specific needs of cargo bikes (e.g. parameters of clearance profile, parking space). The requirements of different groups of cargo bike users may also vary, e.g. depending on the cargo bike type used.
When the cargo bikes use common infrastructure with other transport means, it can affect the traffic flow in cities, both in terms of safety and capacity. Based on the analysis, the article defines the possibilities for sustainable integration of cargo bikes into the urban space.
KEY WORDS: *cargo bike, traffic flows, urban planning, sustainable transport*

1. Introduction

Cargo bikes have gained popularity in recent years in both the commercial and private spheres, especially in Europe and North America. They are mainly used as an alternative transport mode which complements car transport. Exploiting the potential of cargo bikes in optimal way can contribute to sustainable urban mobility. The reduction of emissions and savings of fossil fuels are the main benefits. Initial surveys suggest that during the Covid 19 pandemic, there has been an increase in interest in cycling including the use of cargo bikes, especially for delivery purposes [6,15].

Some research studies show that the cargo bike can be more time-efficient than a car in densely populated agglomerations under optimal conditions. [3,9]. Setting the right conditions is crucial, as the movement of cargo bikes in regular traffic can also have negative effects, such as congestions and traffic safety deterioration.

The article focuses on defining the factors influencing the integration of cargo bikes into urban space. The number and structure of cargo bike users is expanding along with the availability of different types of cargo bikes. The behavior of these users in traffic can affect the traffic flow in the city to varying degrees. Each user may have different preferences, which also depend on local conditions. as shown in [2,7,13]. E.g. the courier service will prefer faster routes and bikes with larger capacity. In contrast, a parent who takes a child to kindergarten is likely to choose the safest possible route and bike. Based on the analysis, this article specifies the influence of the cycle traffic with cargo bikes on the capacity and traffic safety.

2. Analysis of users of cargo bikes

Users of cargo bikes can be divided into two main groups - commercial users and private users. Both of these groups can be divided into subgroups of users who share certain common features. The group of ***commercial users*** includes:

- courier service providers (mail and parcel delivery),
- delivery services (e.g. food, groceries, flowers),
- specific delivery services (e.g. blood samples),
- mobile sales,
- municipal waste collection.

The main goal for courier and delivery services is to serve a given number of customers as quickly as possible. In this case, the couriers move in regular traffic. They can use cycle paths and roads together with motorized vehicles. Delivery routes can be predetermined in the case of serving a constant group of customers in a given area. When the group of customers is variable, it is possible to use software applications for dynamic route planning.[10,14].

Commercial cyclists have very limited possibility to adapt the route and timing of the ride to current conditions, such as weather or traffic. Because of this, e.g., it may happen that the commercial cyclist may be at increased risk of collisions and injury during peak-times of traffic [5]. Mobile bicycle shops are usually moved to the point of sale in the morning, where they offer their services during the day and they return to the home depot after the sale ends. They can also change the point of sale during the day. Therefore, they move for a shorter time in regular traffic, partly at peak times. Cargo bike for mobile sale often has a unique shape and dimensions and, depending on the type of load, can move more slowly, which can also affect the traffic flows. Waste collection service usually uses predetermined routes with predetermined points of service, which are served in given times. In this case, it is possible to schedule the system to avoid peak times of traffic.

Private users use cargo bikes:

- for the transport of children (to kindergarten, school, leisure activities…),
- for shopping (food and consumer goods),
- as a transport mean for people with reduced mobility.

What all private users have in common is that they can easily choose another mode of transport in case of unfavourable conditions (e.g. weather). The user who takes children to kindergarten is likely to prefer the safest possible routes. The timing of the ride depends on the purpose of the trip (e.g. school times) and it is therefore not always possible to avoid peak-times of traffic. It is difficult to generalize the preferences of users who use cargo bike for shopping. In this case, the experience and personality of the cyclist will be largely decisive. These users have very good possibility to plan a ride outside of peak-times of traffic. The group of people with reduced mobility is relatively diverse [8] and can use the cargo bike as a means of transport, but also for shopping. This group of users will pay attention to safety and will move slowly. At the same time, this group of users has very good possibility to plan its ride according to current conditions. A specific group of cargo bike operators/users consists of providers of cargo bike sharing systems and cargo bike rental systems.

3. Cargo bike choosing criteria and variants

3.1. Criteria

The commercial operator of a cargo bike system can use multi-criteria analysis for selecting a suitable bike. The goal is to select a suitable cargo bike type based on a predefined service model. The private user also usually assesses the variants according to the selected criteria, but the evaluation is mostly intuitive. The procedure for evaluating variants is given by the following steps:

STEP 1: Setting the goal → selection of a suitable type of bike.

STEP 2: Determining the set of variants $X = \{X_1, X_2, \ldots, X_n\}$ → available types of cargo bikes (including the possibility of customization).
Determining the se of criteria $Y = \{Y_1, Y_2, \ldots, Y_k\}$ → cargo bike requirements.

STEP 3: Partial evaluation of all variants (sorting) according to individual criteria.

STEP 4: Aggregation of partial evaluations into the final overall evaluation and selection of the optimal variant.

The advantage of this approach is the possibility to take into account the weight of individual criteria. Based on the analysis of user groups, we determined a set of criteria that can influence the selection of the cargo bike for all user groups (Table 1).

Table 1

Set of criteria for select a suitable cargo bike

Group of criteria	Criterion
Economic	Initial investment..
	Method of purchasing the bike (cash, instalments, leasing…)
	Energy consumption of e-bikes.
	Operating costs (e.g. maintenance and repairs, battery replacement).
Technical	Cargo bike parameters (dimensions, load capacity, weight, number of wheels).
	Drive ability (stability, manoeuvrability, steering control…).
	Steering design (gears, brakes, handlebars…).
	Drive type (mechanical or electric).
	Lifespan.
	Availability of service (maintenance and repairs).
	Driving distance on one charge for e-bikes.
	Resistance to damage (e.g. due to weather conditions, driving on uneven surface…)
	Operating characteristics (operating conditions, routes…)
Transportation	Cargo bike design (location of cargo space, weather protection…)
	Cargo type.
	Dimensions and volume of cargo space.
	Ergonomics.
	Possibility to secure cargo and bike against theft.
Logistic	Specific requirements arising from the purpose for which the bicycle is used (e.g. thermal insulation for food distribution, fitting of safety belts for passenger transport…)
	Used transport unit (dimensions, shape and storability).
	Parking options.
	Equipment with navigation and tracking systems..
Legislation	Legislation terms and regulations (e.g. e-bike definition in legislation, maximum speed….)
	Fees and exemption from certain fees (e.g. taxes, insurance, fees required by the municipality…)

3.2. Variants

The offer of various cargo bike types on the market is currently relatively wide with good possibilities for the production of custom made bikes. The load capacity of the cargo bike is up to 300 kg. The width ranges from 60 cm for two-wheel cargo bike to approx. 100 cm for multi-wheel cargo bike. Two- and three-wheel variants are available with both electric and mechanical drives. For multi-wheel variants, the electric motor is standard equipment. Table 2 summarizes the most common types of cargo bikes and their properties that may affect their integration into urban space [1,4].

Table 2

Types of cargo bikes

Cargo bike design		Suitable especially for	Drive ability
Number of wheels	Cargo space		
two	front and rear	private users, courier and delivery services	good maneuvrability, good driving dynamics, possibility to use cycle paths, weaker driving stability, good possibility for parking
	front	courier services, specific delivery services	
	rear	courier services	
three	front	private users, mobile sales, specific delivery services	good stability, good driving dynamics, slower in corners
	rear	courier and delivery services, mobile sales, people with reduced mobility	
four	rear	courier and delivery services,	good stability, large dimensions – worse possibilities for parking
multi-wheel	rear (trailer)	courier services, waste collection	good stability, worse possibilities for parking larger turning radius not suitable for standard cycle paths

4. Integration of cargo bikes into the urban space

4.1. The impact of cycle traffic with cargo bikes on the safety and traffic flows

Design and size of cargo bike, especially its width, can significantly influence the possibility to use standard cycle paths. This could be a limiting factor for using a cargo bike in so-called associated transport space (space for pedestrians and cyclists).

Many cities in the Czech Republic are already actively applying a strategy for the integration of bicycle transport into the transport system. However, the infrastructure they build respects needs of standard passenger bicycle transport. The width of the lanes for cyclists is often at the limit of the minimum possible width even due to the insufficient width of the street space. The infrastructure in the associated space is therefore accessible to cargo bikes with small to medium capacity, i.e.. bikes with two, or three wheels. Separate paths for cyclists with two-way traffic are the exceptions. But this type of paths is rare in continuously built-up areas in the Czech Republic.

Large cargo bikes will thus mainly move in the main transport space (space for motorized transport), where they can use the infrastructure for cyclists. But their driving profile in many cases will exceed the width of the protective or reserved lanes. The width of cargo bikes can therefore be the cause of the "reluctance" to accept them by other users of the main transport space.

In the Czech Republic, there are currently ongoing discussions on the safety of bicycle operation in the main transport space. On 14 April 2021, after some postponements, the Czech Chamber of Deputies voted for an important change in the rules for overtaking cyclists. The law, which regulates the traffic rules on roads, proposes a more precise definition of the safe lateral distance when overtaking a cyclist. Safe lateral distance when overtaking a cyclist means the distance between the nearest edges of the motor vehicle, trailer or load and the bicycle, bike trailer or cyclist. If this proposal goes through other legislative steps, drivers will have to maintain a lateral distance of at least 1.5 meters between the car and the bike. A minimum safety distance of 1 meter will apply in sections with permitted maximum speed of 30 km / h. The Czech Republic will thus join other countries where this rule is already regulated by law. Safety distances are specifically set by law e.g. in Germany, France, Spain, Portugal or Belgium. The police control and enforce the safe distance even in countries where it is not precisely defined, such as the United Kingdom.

The concern about the flow of road traffic is a frequent objection to approve this distance. In the built-up area, the width of the road of two-way roads with low traffic is 5.5 meters, but often 6.5 meters or more. Narrowing the road to the minimum possible width is also a consequence of traffic-calming measures, especially where parking lanes are a part of the main transport space. Even so, two cars can pass by (avoid) on all two-way roads. There is therefore a presumption that it is possible to overtake a cyclist on these roads, even on a cargo bike. The width of cargo bike is usually up to 1 m. The width of the standard lane should be enough for overtaking, or the vehicle driver can also cross into the opposite lane when overtaking. Quite exceptionally, it is also possible to design a two-way road with a width of 3.5 meters, e.g. in residential areas. On these roads, vehicles can pass by each other only in points designated for this purpose (every 80 to 100 meters). The speed on such roads is usually limited to the maximum permitted speed of 30 km / h, which is already very close to the speed of cyclists. Even here, however, overtaking a cyclist on a truck should be possible.

Table 3 shows the differences in the passage times of road sections of a certain length when the speed of the vehicle is reduced and the cyclist cannot be safely overtaken. These values show that possible slowdown has no significant effect on travel time or on the flow of road traffic.

Table 3

Differences in the passage time of a section when the speed is reduced due to drive behind a cyclist

Speed reduction [$km.h^{-1}$]	Difference in the passage time according to length of road sections [s]							
	10 m	20 m	30 m	50 m	100 m	200 m	500 m	1000 m
from 50 to 30	0,48	0,96	1,44	2,4	4,8	9,6	24	48
from 50 to 20	1,08	2,16	3,24	5,4	10,8	21,6	54	108
from 50 to 10	2,88	5,76	8,64	14,4	28,8	57,6	144	288
from 30 to 20	0,6	1,2	1,8	3	6	12	30	60
from 30 to 10	2,4	4,8	7,2	12	24	48	120	240

When assessing travel time and traffic flow, it is also necessary to take into account other factors that affect the traffic flow, or causes the effect of the congestions. These factors include e.g. preference for pedestrians at crosswalks or delays at intersections.

4.2 The impact of cycle traffic with cargo bikes on the capacity

The design of intersections and sections between intersections is to be solved as a whole in terms of safety and usability of the infrastructure for cyclists. In particular, the spatial possibilities of intersections will influence, and usually predetermine, the possibilities of designing the sections between intersections.

In the Czech Republic, calculations of intersection capacities are regulated by the methodology published in the so-called Technical Conditions. [11] However, they do not currently sufficiently cover the impact of cyclist traffic. For all types of intersections, the composition of traffic flows is taken into account by recalculating individual types of vehicles (including bicycles) into unit (recalculated) vehicles. The question is whether the current coefficients are also applicable to cargo bikes. For uncontrolled intersections and small roundabouts, the further consideration of cycle traffic on the capacity of the junction already depends on the individual solver. This can reflect the cycle traffic in the parameters that affect the capacity of intersections, especially within the gaps in the superior and subordinate traffic flows. For intersections controlled by traffic lights, the cycle traffic is taken into account by determining the so-called split times, i.e. the intervals from the end of the green-light time on the traffic light for one direction to the beginning the green-light time on the traffic light for the direction in collision course. In the case of gaps, parameters depend on the subordinate traffic flows, and in the case of split times, indirectly on the possible start-up or acceleration of the vehicle. It is important to note that in the case that cycling integration measures are not implemented on the road, cyclists must be allowed to move in intersections in joint traffic with other vehicles. Cycle traffic at intersections is regulated by Technical Conditions “TP 179 Design of Roads for Cyclists” [12].

In the case of uncontrolled intersections or junctions, it is appropriate to implement cycling measures primarily for the direct direction, or and other directions that need to be preferred with regard to the cycling routes. These are mainly the "Pictograms corridor for cyclists", a protective or reserved lane for cyclists, a separate shift lane, etc. These measures do not depend on whether they are used by cyclists on passenger or cargo bikes. Properly implemented, these measures can significantly increase traffic safety at an intersection. In superior traffic flows, these measures do not usually affect the capacity of the intersection. These measures can be similar to turn- and through lanes for other vehicles in the assessment of the capacity of individual entrances. At larger intersections, the lower speed of cyclists in superior traffic flows may affect the usability of gaps in superior traffic flows. In the case of absence of any measures for cyclists (vehicles should not overtake cyclists or ride with them at the same time), thanks to the lower speed of cyclists, these gaps will increase. This will increase their usability for vehicles from subordinate traffic flows. Conversely, when using measures, cyclists may ride and overtake at the same time. The gaps in the superior traffic flows will thus decrease with higher intensity of cyclists.

The Technical Conditions “TP 179” [12] recommend the construction of smaller and more compact roundabouts in municipalities with regard to the safety of cyclists. If cyclists move in the main transport space, they do not have a significant effect on the capacity of mini and small roundabouts with an outer diameter up to about 30 m. Bikes usually move at roundabouts at a comparable speed as motor vehicles. Other vehicles move on a roundabout behind bikes, so it does not depend on whether it is a passenger or cargo bike. Roundabouts with an outer diameter above approx. 30 m, small roundabouts with a traffic intensity of more than 10,000 vehicles / 24 hours or with a higher share of buses and trucks in the traffic flow, turbo roundabouts and roundabouts with more lanes at the entrance and the circuit are not suitable for guiding cyclists in the main traffic area with regard to traffic safety. If cyclists move in an associated transport space, they may affect the capacity of the intersection if a separate cycle path is connected to the roundabout. The inclusion of another entrance to the intersection will create additional collision points in the intersection, which will affect the size of critical gaps. In certain cases, the capacity of the intersection may be reduced, especially at the previous and subsequent entrances to the intersection.

In the case of intersections controlled by traffic lights, the different speeds and nature of the movement of bicycles and motor vehicles may give rise to requirements for partial or more extensive modifications to take account of cycling traffic, especially at larger junctions. It can be either the creation of separate measures for bicycles or the adjustment of the control of traffic lights and split times for movement in common traffic, etc., depending on the needs of a given intersection. Due to the lower speed of cyclists, the cycle traffic at larger intersections can increase the split times and thus reduce the capacity of the intersection. For this reason, it is appropriate to consider such measures as separate bicycle traffic lights at the entrance to the intersection or an internal transverse line connected to the signal in the area of the intersection, which will allow to shorten the necessary split times. However, cycling measures that are implemented "inside" such large intersections must respect the size of the bicycle, in this case also the length. This could create a problem for cargo bikes and make it impossible to use such measures.

5. Conclusions

It follows from the above that the size of the bike does not affect the capacity of the intersection, except for measures "inside" the intersection controlled by a traffic light. It does not matter whether the cyclist moves on the standard or cargo bike at the intersection. However, capacity can be affected by bike speed. This depends on the cyclist's behavior, but also on the load on the cargo bike and its design. Therefore, not only the dimensions of cargo bike (the possibility of using it in associated transport space) but also its operating parameters (speed, acceleration) are important for choosing a suitable cargo bike with regard to traffic flows in urban areas.

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