Which is faster over the last mile: Cargo cycle or car?

Starting point

In these times of driving bans and emissions manipulation, it is becoming ever clearer that new traffic solutions are needed, including for last-mile deliveries. On the one hand, this is a growing field thanks to the booming e-commerce market; on the other, it conflicts with societal goals such as air purification, climate policy and urban quality of life. Funded by the German Federal Ministry of the Environment, the Institute of Transport Research within the German Aerospace Center (DLR) is examining the use of cargo cycles for urban freight transport and last-mile service trips. To this end, hundreds of businesses and public institutions are taking part in Europe's largest commercial cargo cycle trial: "Ich entlaste Städte" ("Taking the load off cities"). What they want to know is: "How fast are we when we use cargo cycles rather than cars in our daily routine?" Project manager Johannes Gruber and his team have answered this question and are now able to present the factors which influence travel time differences between cargo cycles and cars.

No. of wheels	Construction type	Side view	No. of models	No. of vehicles
2	Pizza delivery bike		1	8
	Long John bike		9	56
3	Longtail bike		2	4
	Trike, front load		5	15
	Heavy-load tricycle		1	1

Figure 1: The fleet consists of five cargo cycle construction types. Most of the 18 different models are outfitted with electric pedal assists up to 25 km/h (~ 15.5 miles/h), which require no driver's license or registration.

Data and methodology

Eighty-four businesses, public institutions and organizations across Germany supplied the data, which was evaluated over the course of the project. They undertook a total of 1,421 commercial trips with, collectively, 18 different cargo cycle models (see figure 1). Participants tracked their trips autonomously using a project-specific app. Each trip was subsequently compared to a virtual car trip by using Google Maps, taking into consideration origin and destination as well as traffic conditions. The partly overlapping distribution of cargo cycle and car travel times is shown in figure 2. For distances below three kilometers, cargo cycles and cars have almost identical travel times; above five kilometers the differences become more pronounced.

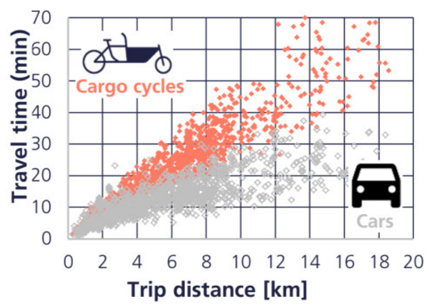

Figure 2: Distribution of travel times of cargo cycles (orange) and cars (gray), with a noticeable overlap in the range up to around three kilometers.

We are interested in how these differences come about; that is, how we can describe a systematic connection between observed reality and measurable characteristics. This can be achieved with regression analysis. The application of standard models was hampered by data challenges such as heteroscedasticity and cluster effects. After following a multi-step procedure, what is known as a random intercept model was selected; this gives the best values for the goodness of fit indicators. For this reason, we have used it to depict the travel time differences between cargo cycles and cars.

In January 2019, this paper received the "Best Research Paper" award from the Urban Freight Transportation Committee (AT025) of the Transportation Research Board (TRB).

The associated academic article was published under the title "Travel Time Differences Between Cargo Cycles and Cars in Commercial Transport Operations" in the journal *Transportation Research Record*. The authors of this paper are Johannes Gruber of the DLR Institute for Transport Research and Santhanakrishnan Narayanan of the Technical University of Munich.

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Determinants of travel time differences

Figure 3 lists the variables which significantly influence the travel time differences between cargo cycles and cars within the context of urban commercial transport trips up to 20 kilometers. These variables can be subdivided into four categories: *Spatial context*, *temporal variables*, *vehicular variables*, and *trip-specific variables*.
The intercept value can be interpreted as a "built-in" superiority of cars over cargo cycles amounting to 2.3 minutes per trip. Longer distances also favor the car: For each additional kilometer of trip distance, cars gain a time-saving benefit of 1.7 minutes.
The advantages favoring cargo cycles become especially apparent when looking at existing shortcuts for bicycles, e.g. through parks or along one-way streets that are bidirectional for bicycles, as well as on trips during rush hour early in the day. In the case of the latter, cars have a travel time disadvantage of 1.3 minutes. Fast motorizations up to 45 km/h (~28 miles/h) allow for further advantages when using cargo cycles. The influence of trip-specific conditions – such as weather, trip purpose, or the degree to which the cargo box was filled – has not been found to be significant within the scope of this analysis.

	Variable	Estimate	t. stats
	Intercept	2.318	***
Spatial cont.	Cargo cycle trip distance [km]	1.696	***
	Elevation difference w/out electr. assist [m]	0.129	***
	Elevation difference w/ electric assist [m]	0.020	***
	Shortcuts for bicycles [km]	-1.665	***
	log(Car ownership per 1,000 inhabitants)	-0.512	***
Time	Trip started between 6 and 10 a.m.	-1.318	***
	Trip started between 10 a.m. and 7 p.m.	-0.993	***
Veh.	Three-wheeled cargo cycle was used	2.066	***
	Fast e-bike (45 km/h ~28 miles/h) was used	-1.292	*
	Standard deviation of intercept	1.126	
Trip	Insignificant: weather, trip purpose, payload utilization etc.		

Figure 3: Determinants for the variable "Difference in travel time of cargo cycles compared to cars in minutes"
Negative coefficients (in orange) show travel time benefits for cargo cycles; positive coefficients, for cars.

Model applications: Car courier data set and congested scenario analysis

Furthermore, we examined the degree to which differences between cargo cycles and cars vary depending on different traffic conditions, as is the case with congestion or traffic calming. Figure 4 depicts the travel time differences between cargo cycles and cars as probability curves. The blue curve represents the base distribution of the data within the examined *sample*. Half of all cargo cycle trips (dashed line at 50 %) take a maximum of seven minutes longer; 10 % of them are currently already faster than by car. Alongside this curve we can find two additional distributions: Using the model results, virtual cargo cycle travel times for around 10,000 *car courier trips* were calculated. The result is a shifting of the s-curve towards the right, meaning longer travel times for cargo cycles.
The *congested scenario* with worse traffic conditions for cars also yielded new values for the travel time differences. The shifting of the s-curve towards the left depicts a situation in which cargo cycles are clearly in a more advantageous position: Around 40 % of all trips would be completed in a shorter time when using cargo cycles rather than cars.

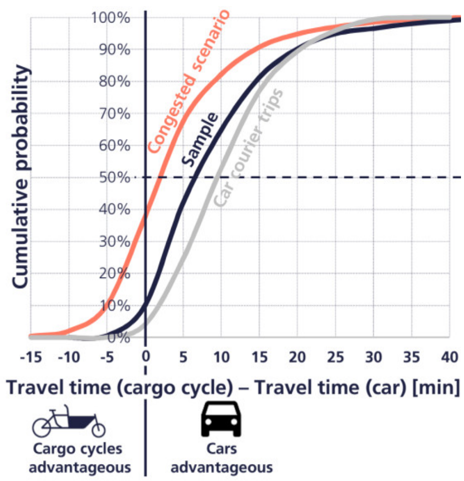

Figure 4: Travel time differences between cargo cycles and cars in the *sample* data set (blue curve), the *car courier* data set (gray curve), and within the *congested scenario analysis* (orange curve).

Results and conclusions

- Currently, cars are, on average, still superior to cargo cycles, yet we do see definite overlap for trip distances up to three kilometers. This shows practitioners a potentially very attractive range for the use of cargo cycles e.g. for micro-hub concepts.
- Our regression model yields valuable insights into understanding the different travel times of cargo cycles and cars.
- Fifty percent of all trips would take only a maximum of two to ten minutes longer if shifted from car to cargo cycle. It should be noted, however, that additional time for finding a parking spot or walking to the precise destination point was not considered; this could noticeably diminish the car's advantage.
- Small modifications to the travel time advantages currently exhibited by conventional delivery vehicles (such as through more rigorous penalization of double parking) can be enough to have substantial effects. This finding is particularly relevant for transport policy makers.

The path towards a sustainable and efficient last-mile transport system is a long one. Using our research findings based on the real experiences of businesses and institutions, the DLR Institute of Transport Research is making a contribution towards achieving this goal.

Deutsches Zentrum für Luft- und Raumfahrt (DLR), German Aerospace Center
Institute of Transport Research • Rudower Chaussee 7, 12489 Berlin, Germany
Author: Johannes Gruber • Telephone: 030 67055-200 • Email: johannes.gruber@dlr.de • DLR.de/vf

Deutsches Zentrum für Luft- und Raumfahrt
German Aerospace Center