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TEST PROPOSAL PROJECT CARGO BIKES

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1 Introduction

Commissioned by Connekt / Top Sector Logistics Netherlands, HAN-Automotive is conducting an extensive and independent experimental research into a number of aspects of Light Electric Vehicle (LEV) category cargo bikes. Cargo bikes are available in various forms and designs such as "Single track", "Multi-track", only electrically driven or partly electrically supported with various loading capacities. This research quest focuses on the types of cargo bikes that are already available on the consumer market or will be made available shortly. The most common cargo bike category on the consumer market is the type of cargo bike that is partly electrically supported with maximum continuous electric motor power of 250 [W]. Regulation wise in Europe, this category of cargo bikes must full fill requirements described in EN 15194:2017 (Electrically Pedal Assisted Cycles (EPAC)). Only this category of cargo bikes, with a load capacity from 100 [kg] to 300 [kg], is going to be a matter of research in this study.

This experimental research covers four different aspects of cargo bikes such as:

- Braking performance
- Stability / Controllability
- Battery range
- Technical assessment of the cargo bikes

Every research aspect mentioned above is investigated by means of one or more tests. The test methods and the associated test procedures are covered in this proposal.

2 Braking performance

2.1 Introduction

The cargo bike is mainly used in inner city areas for transporting of goods. When necessary, a cargo bike must be brought safely to standstill within an acceptable distance by operating the brakes. The brake performance of these bikes is a matter of investigation. A series of tests will be performed to study the brake performance of the to be tested cargo bikes.

2.2 Test method and procedure

As there are not any common and specific set of rules, regulation or testing norms for this type of vehicles on the European level, HAN-Automotive has investigated the existing norms and the norms of individual member states to determine the set of requirements needed to assess the brake performance of these cargo bikes.

The European norm EN 15194:2017 only covers the set of requirements for assessing the brake performance of only two wheeled (single track) cargo bikes. The brake performance assessment of multi-track cargo bikes is covered neither in this norm nor in any other European norm. To be able to create an acceptable and defined baseline for the assessment of the braking performance of the single track and the multi-track cargo bikes with similar testing conditions and testing requirements, the recently published DIN 79010:2019 is going to be applied. The test procedures and test methods described in this norm is determined specific for single track and multi-track cargo bikes. This norm is complimentary to the NEN-EN-ISO 4210-2:2015 which is applied for assessing of normal city bikes on several aspects such as braking performance.

The braking performance assessment test is going to be performed on a prepared test track at HAN-Automotive. Summarized the following handlings are going to be performed to assess the braking performance of the cargo bikes:

- Each cargo bike will be instrumented and prepared as described in NEN-EN-ISO 4210-4:2014 (4.6.3.2)
- The performance test is will be performed on a pre-defined test track as defined in NEN-EN-ISO 4210-4:2014 (4.6.3.1)
- The applied force at the handgrip shall not exceed 180 [N]
- The test will be performed as well under dry conditions as wet conditions as described in DIN 79010:2019 and NEN-EN-ISO 4210-4:2014
- The test will be performed as stated in DIN 79010:2019 (5.5.1.2)
- Each cargo bike will be tested with maximum allowable load as defined by the manufacturers
- Each cargo bike will be tested without any extra added load except the load of the test person
- The brake test will be carried out with maximum initial speed between 12.5 [km/h] and 25 [km/h]. The initial speeds will be documented
- In case of multi-track cargo bike, during braking it shall not leave the lane more than 5 [%]
- When tested, the cargo bikes must meet the requirements listed in Table 1

Type of bicycle	Condition	Brake in use	Minimum braking deceleration
Cargo bike	Dry	All axles	3.4 m/s^2
	Wet	All axles	2.2 m/s^2
	Dry	One axle	2.2 m/s^2
	Wet	One axle	1.4 m/s^2

Table 1 Minimum braking deceleration values for cargo bikes

2.3 Data measuring and collecting

During performance of the test the specified data specified in NEN-EN-ISO 4210-4:2014 will be digitally measured and the data will be collected accordingly.

To be measured data:

- Wind speed of the test track
- Acceleration of the cargo bike
- Force applied to the brake levers
- Speed of the cargo bike

The data will be collected with frequency of 10 [Hz] and all the data will be logged by means of a data logger.

2.4 Data processing

After collecting of the test data, the data will be analyzed and processed accordingly. The test results will be presented in form of graphs with definition.

3 Stability / controllability

3.1 Introduction

Stability is one of the main aspects of this research as it has a direct link to the way these cargo bikes are applied to carry maximum load and how they maneuver through the city centers with tight corners and speeds up to 25 km/h when electrically assisted. For assessing the dynamic stability of these types of transport vehicles, there are nonspecific European norm or regulations of any type. The recently published DIN 79010:2019 defines only procedure and test method for dynamic stability assessment of the multi-track cargo bikes. In addition to this HAN-Automotive is willing to investigate the possibilities by conducting of different types of tests for establishing robust procedure(s) and test method(s) to assess the stability / controllability of different types of cargo bikes under different conditions, such as: different load capacities, different vehicle speeds and the influence of maneuvering. The to be established test method(s) and procedure(s) must be applicable for different types of cargo bikes available on the consumers market. In the following different predefined tests and test set ups will be discussed.

3.2 Type of tests

During testing, several different tests will be performed in order to establish an efficient procedure of assessing the stability / controllability of the cargo bikes. For assessing the stability, the designated tests can be divided into two subcategories such as: Static stability test and dynamic.

3.3 Static stability

The static stability assessment of the cargo bikes is based on the tilting stability and parking stability as well in loaded as in unloaded conditions. This applies to both the single tracks and the multi-tracks.

3.3.1 Test procedure and method

The test procedure and test method defined in DIN 79010:2019 will be followed to assess the static stability of the cargo bikes.

3.3.2 Data processing

The assessment of the cargo bikes will be filmed and recorded. After analyzing the videos, it will be declared if the cargo bike fulfills the requirement or not.

3.4 Dynamic stability

The dynamic stability of multiple track cargo bikes is covered in DIN 79010:2019 but for single track, there is neither a norm nor a regulation which covers the dynamic stability assessment part.

3.4.1 Type of assessment tests

The following set of tests can be used to assess the dynamic stability / controllability of the cargo bikes.

- Steady state circle test
- Moose test
- High speed (straight line)

3.4.1.1 Steady state circle test

While turning, single-track cargo bikes will be able to lean into the corner similar to a regular bicycle, however, some cargo bikes are very long compared to regular bicycles which may affect the turning radius. To ensure that the cargo bike can easily navigate in urban areas, they should be able to complete a circle with the minimum radius which may be found in a city. Multi-track cargo bikes do however not have the ability to lean into the corner, meaning they will fall over easier compared to single-track cargo bikes or regular bikes. The multi-track cargo bikes will therefore be required to maintain a smaller velocity to be maintained throughout the circle Figure 1, yet they will have to comply with the same minimum turning radius as single-track cargo bikes and bicycles.

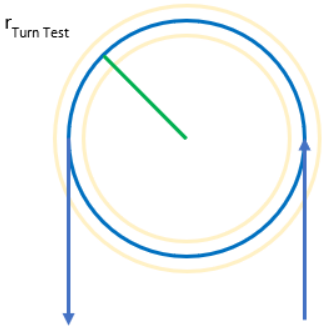


Figure 1 Schematic view of the steady state circle test

3.4.1.1.1 Test procedure and method

During this test the multi-track cargo bikes will be assessed due to DIN 79010:2019. The single track cargo bikes will be also assessed following the test procedure and method as described in the norm, but the initial speed of the vehicle and radius of the circle is a matter of investigation.

3.4.1.1.2 Data measuring and collecting

The speed of the vehicle will be measured and the speed data will be sampled with 10 [HZ]. The data will be logged by means of datalogger. The rest of the assessment will be conducted visually and it may be filmed during the trial.

3.4.1.1.3 Data processing

After the speed data and the videos are analyzed the vehicle will be judged accordingly and will be declared as pass or fail

3.4.1.2 Moose test

The moose test is necessary to assess the controllability of the cargo bikes. When biking, the rider will sometimes have to avoid obstacles. This can be another bike slowing down/stopping, someone falling over or a pedestrian walking onto the bike path without looking. It is therefore very important that a bike can quickly be maneuvered to avoid the obstacle. These sudden changes of direction can influence the stability and handling of the vehicles Figure 2.

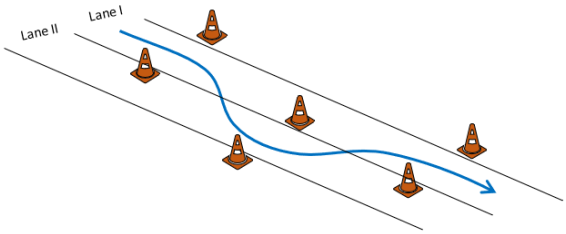


Figure 2 Schematic view of the test site for the moose test

3.4.1.2.1 Test procedure and method

HAN-Automotive is willing to investigate whether by performing such a test, how far controllability / stability of the cargo bikes are affected. The test procedure and test criteria will be determined once all to be tested cargo bikes are available.

3.4.1.2.2 Data measuring and collecting

The speed of the vehicle will be measured and the speed data will be sampled with 10 [HZ]. The data will be logged by means of datalogger. The rest of the assessment will be conducted visually and it may be filmed during the trial.

3.4.1.2.3 Data processing

After the speed data and the videos are analyzed the vehicle will be judged accordingly and will be declared as pass or fail

3.4.1.3 High speed (straight line)

The to be tested category of cargo bikes are all designed to be electrically assisted up to speed of 25 [km/h]. Mostly these kinds of speeds are achieved while riding following a straight line. HAN-Automotive is willing to investigate how this speed will affect the drivability of these cargo bikes.

3.4.1.3.1 Test procedure and method

The test method and the procedures are in general terms as following:

- The cargo bikes will be equipped with a video camera to record the test
- The cargo bikes will be equipped with a speed sensor to record the speed
- If possible and safe the test rider will try to reach a speed of 25 [km/h]
- If possible, the maximum speed of 25 [km/h] will be kept constant for a period of approximately 1 min

3.4.1.3.2 Data measuring and collecting

The speed of the vehicle will be measured and the speed data will be sampled with 10 [HZ]. The data will be logged by means of datalogger. The rest of the assessment will be conducted visually and it may be filmed during the trial.

3.4.1.3.3 Data processing

After the speed data and the videos are analyzed the vehicle will be judged accordingly and will be declared as pass or fail.

4 Battery range test

A series of field tests on the public roads will be conducted to determine the battery range of cargo bikes. A possible cargo delivery scenario in and around the city center of Arnhem will be simulated during these tests. The simulated scenario will include many stop and go moments as this will affect the total battery range of a cargo bike. During these series of tests, measures will be taken into account to decrease the influence of the rider as much as possible. This test will be used to assess the battery range with respect to the specs delivered by the manufacturer.

4.1 Test procedures and method

To determine the number of stop and go moments and the average speed on the road in between the stop and go moments, a series of tests will be performed on two different predefined delivery routes with stop moments at several supermarkets, restaurants and shops. For more details, please see appendix 1 - 3 After defining the average speed and the number of stop and go moments, the test will be simulated on a bike road as sketched in appendix 4.

The following criteria and procedures will be taken into account while performing the tests:

- There will be 3 groups of test individuals
- Each group will consist of 5 individuals
- The cargo bikes will be also divided into 3 sets of 5 bikes per set
- The cargo bike will be loaded with 50 [%] of the maximum allowable load as specified by the manufacturers
- The test groups will be composed according to the body length of the individuals
- The designated test route will be prepared with clear signs on side of the road to represent the stop and go moments
- Each test group will bike together and swap their bikes after each stop with another individual of the same group
- The actual test will take place 3 days in a row to minimize the weather influences.
- Each test day the test group will ride with a different set of cargo bike than the day before
- The test will end in case it is noticed for the first time that there is no electric assistance any available.
- The test method and procedures will be instructed to all individuals
- All the tests will be performed in the highest assistance level of electric driveline
- The test individual is free to choose any gearing during the test ride

4.1.1.1.1 Data measuring and collecting

The data from the cargo bike computer including the data from the mobile app will be collected at the end of each test day.

4.1.1.1.2 Data processing

The test data from 3 days will be analyzed and processed accordingly.

5 Technical assessment of the cargo bikes

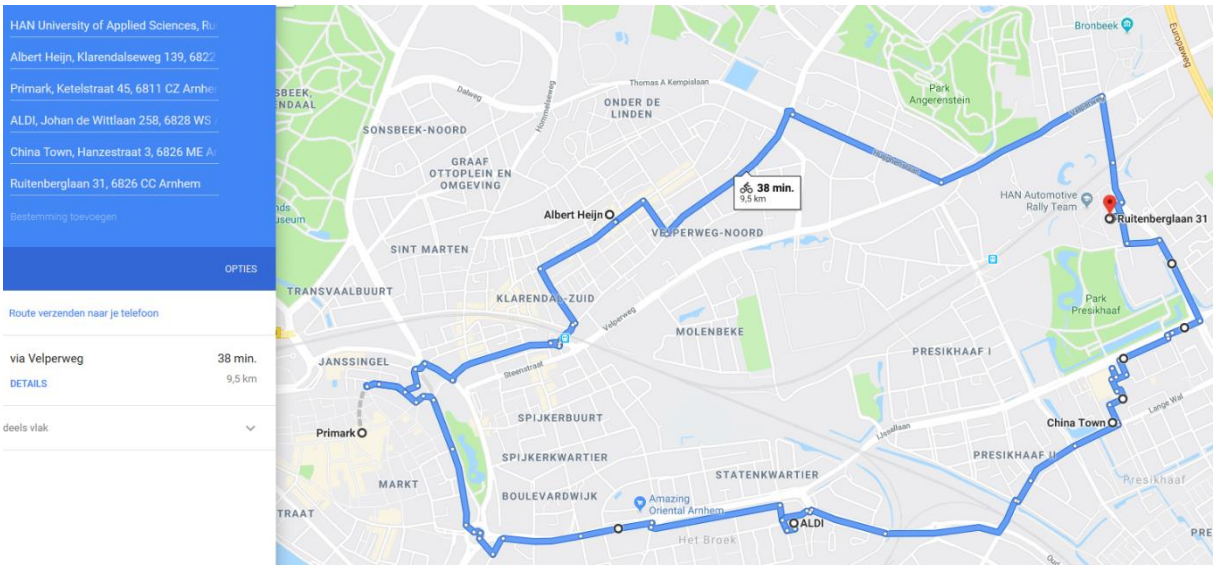
The objective of this assessment is to determine how well the vehicles are designed/produced and prepared to ensure safe use in general and specific in traffic. During this investigation, attention will be paid to safety related preventive measures taken into consideration during the design / production. Among others the following aspects will be assessed:

- Routing of electric and actuation cables
- Structural connections (welding -and bolt connections)
- Sharp edges
- Controlling of play and pretension by components applied with bearings such as wheels, crank etc.
- The effectivity of lights and reflectors

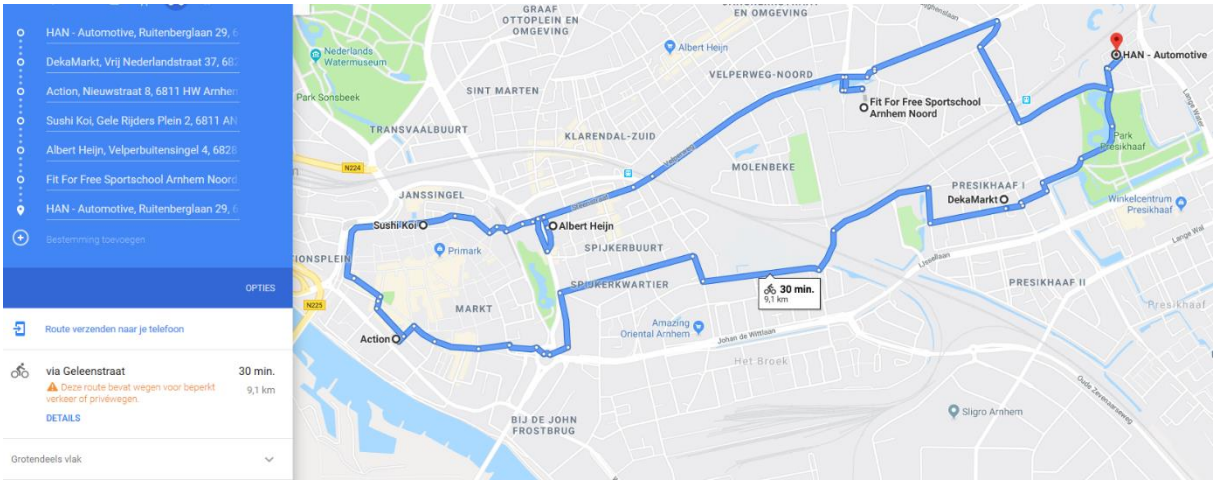
During this investigation, the traction of the cargo bikes with maximum allowable load at an inclination with a to be determined inclination angle will also be assessed. The assessment will be visually performed by an expert from the field of vehicle structural design. The results will be presented in the form of a report per cargo bike.

6 Appendix

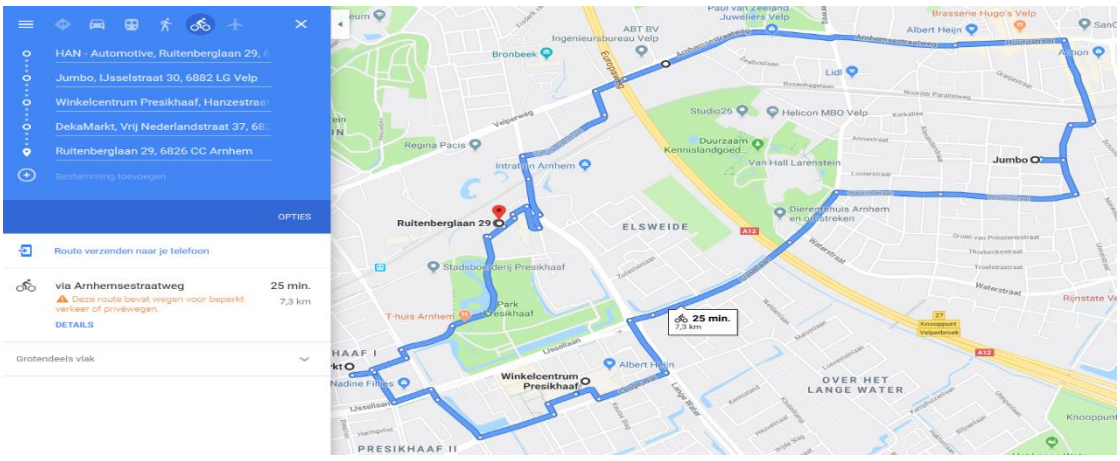
1. Trial route # 1



2. Trial route # 2



3. Trial route # 3



4. Rout where the simulation will take place (test parkour)