

System Theoretic Process Analysis applied to a new mobility concept for automated cargo transport in urban areas

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In Follow-Me mode, the cargo bike automatically follows the rider.

Gefördert durch:



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FSQ
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A BRAND OF WERTEFEST GmbH

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des Deutschen Bundestages

HELIOS

SMART MOBILITY

- ✔ Follow-Me Mode
- ✔ Automotive Steering Technology
- ✔ Use of own control units
- ✔ Prototype-Development
- ✔ Fleet-Management
- ✔ Remote Control
- ✔ Access-Management
- ✔ Evaluation of type approval



Helios aimed to provide an environmentally friendly solution for (sub-)urban logistics.

Motivation

Helios is a **highly automated cargo bike** for **symbiotic mobility** in urban and suburban environments.

Objectives



Rising logistics in urban areas



Increasing traffic and environmental pollution

HELIOS
 SMART MOBILITY

Environmentally friendly mobility concept



Acceptance for (partly-) autonomous vehicles



Flexible and wide scope of application



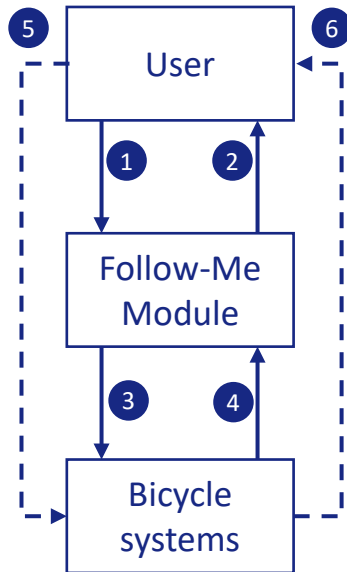
- STPA is especially applied to the Follow-Me Mode exclusively
- The team performing the STPA consisted of experienced Safety Experts which had only theoretical knowledge about the method but are experienced with other methods such as FTA and FMEA
- The analysis was performed at a very early stage in the concept phase (major decisions regarding technologies and architecture have not been made)

Besides safety concerns, STPA was applied to analyze the user experience and acceptance.

L1 Loss of life or injury to people while "Follow-Me" Mode is engaged (user and passenger)

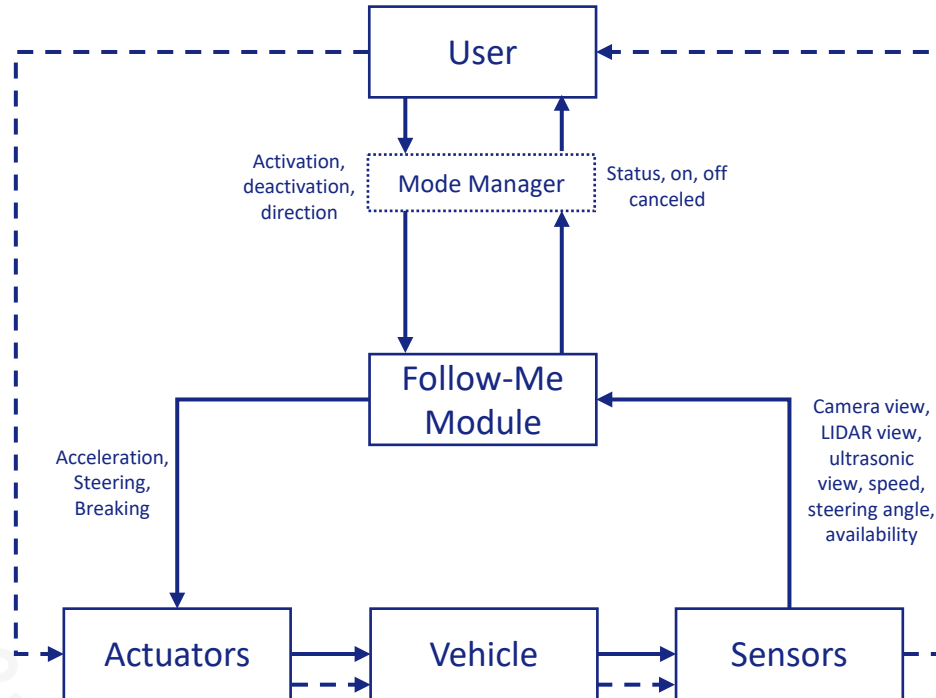
H1: Bicycle violates the minimum safety distance to a pedestrian or the user. [L1]

Control structure – Iteration 1: Single control loop with basic elements

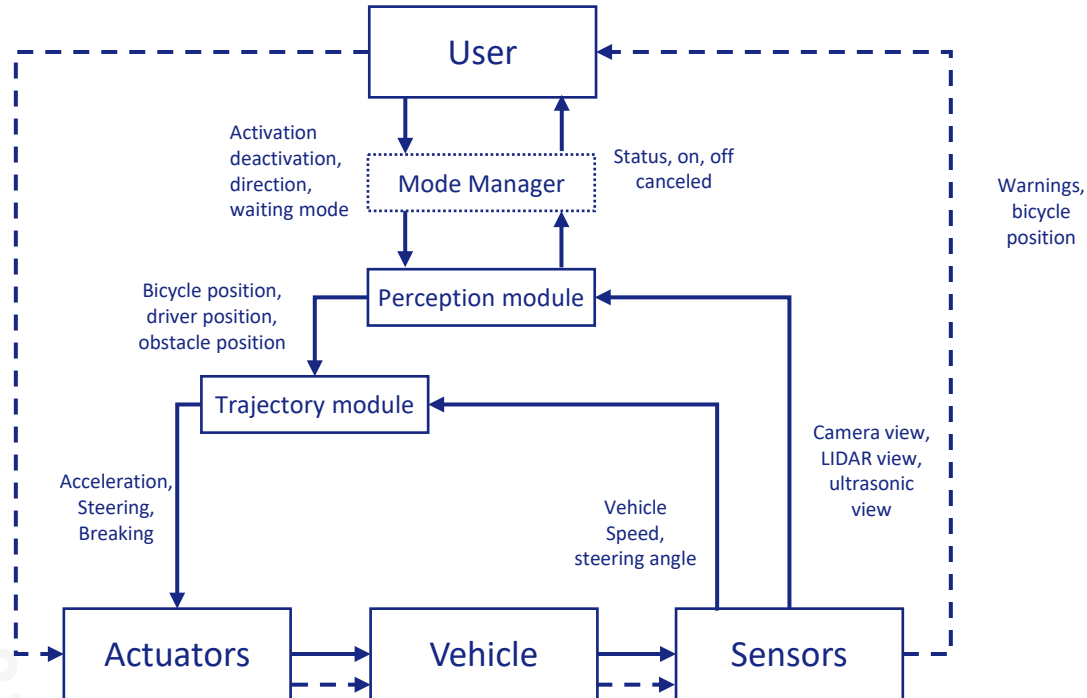


ID	Information
1	User enables / stops Follow Me Mode User walks in front of the bicycle to control the movement
2	Status On, off, canceled, active
3	Steering, acceleration, breaking
4	Position, distance to driver and other obstacles & pedestrians
5	Manual breaking and steering on the vehicle, emergency stop via remote control
6	Bicycle position, warning signals (visual and acoustic)

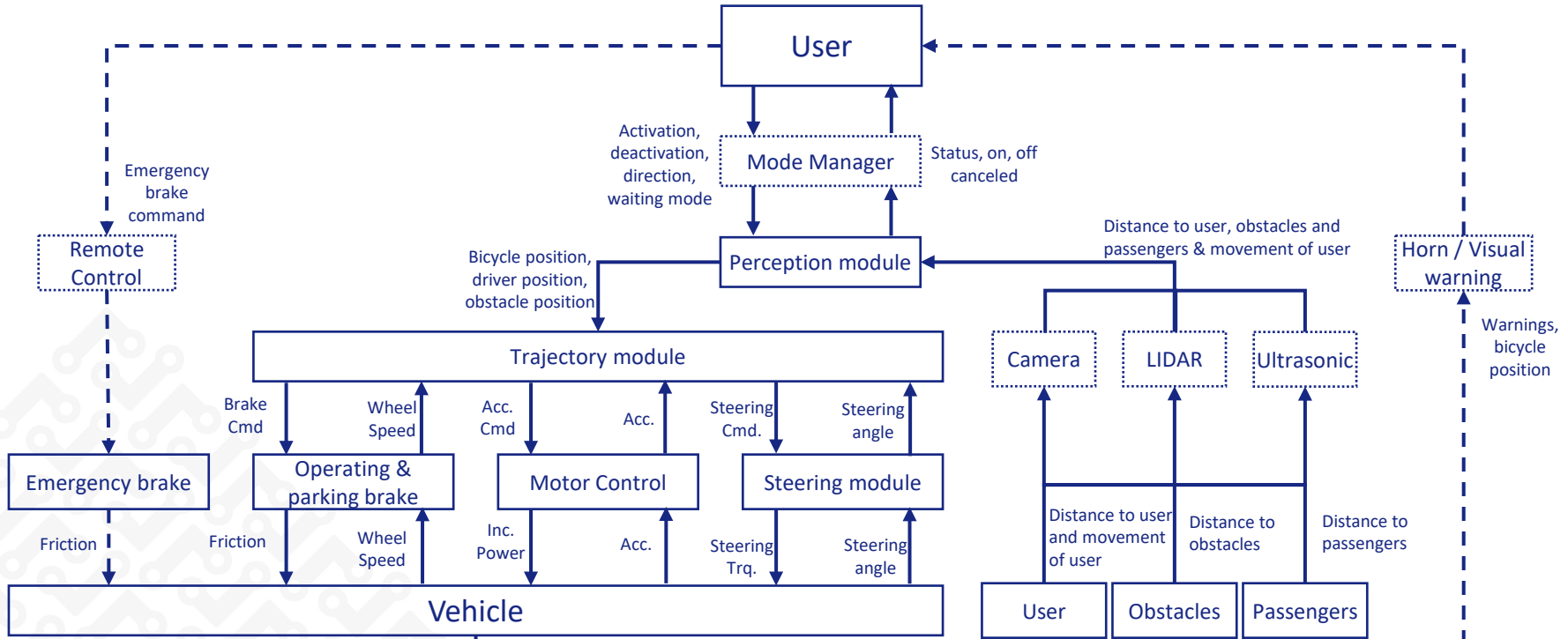
Control structure – Iteration 2: Add mode manager and details on vehicle level



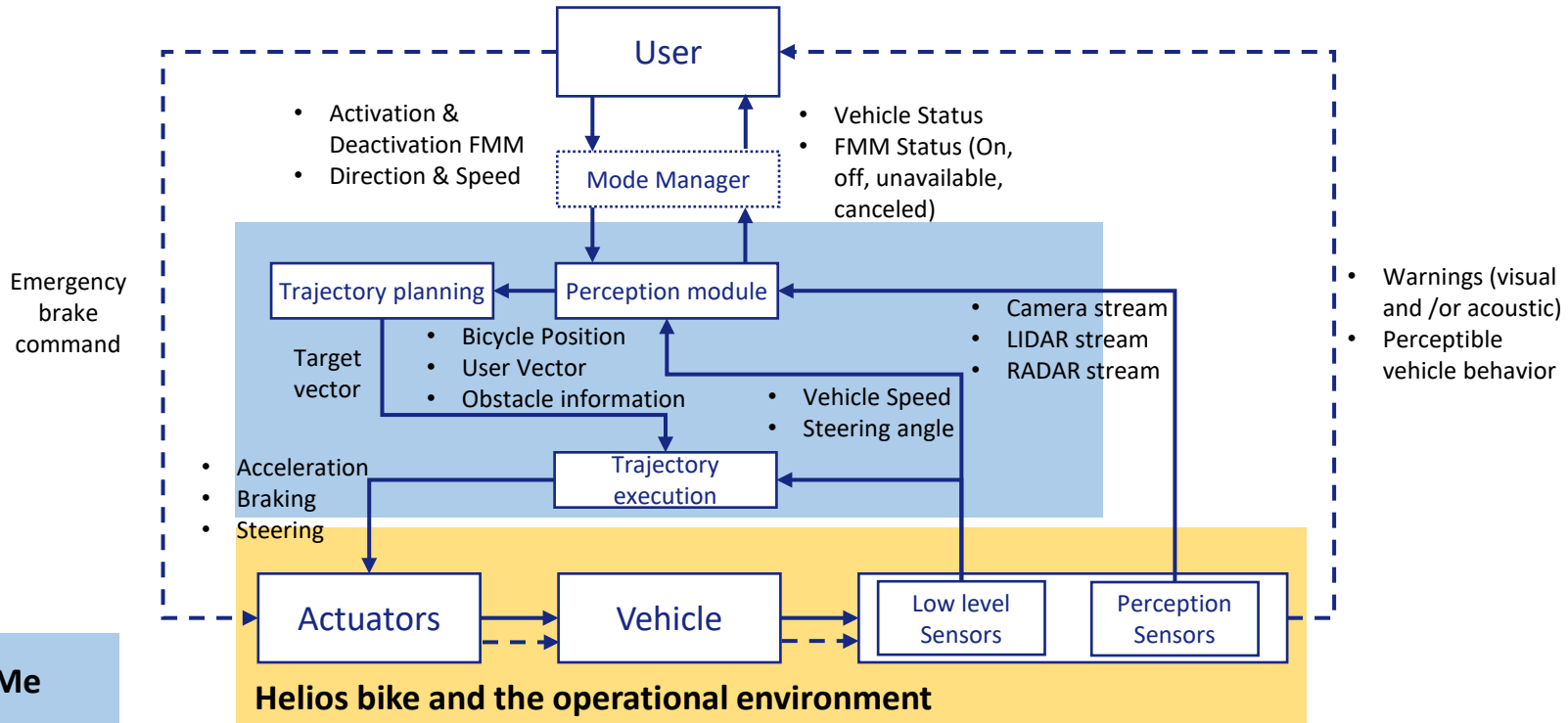
Control structure – Iteration 3: Decomposing the Follow-Me Module



Control structure – Iteration 4: (Too) detailed model of the low-level control loops



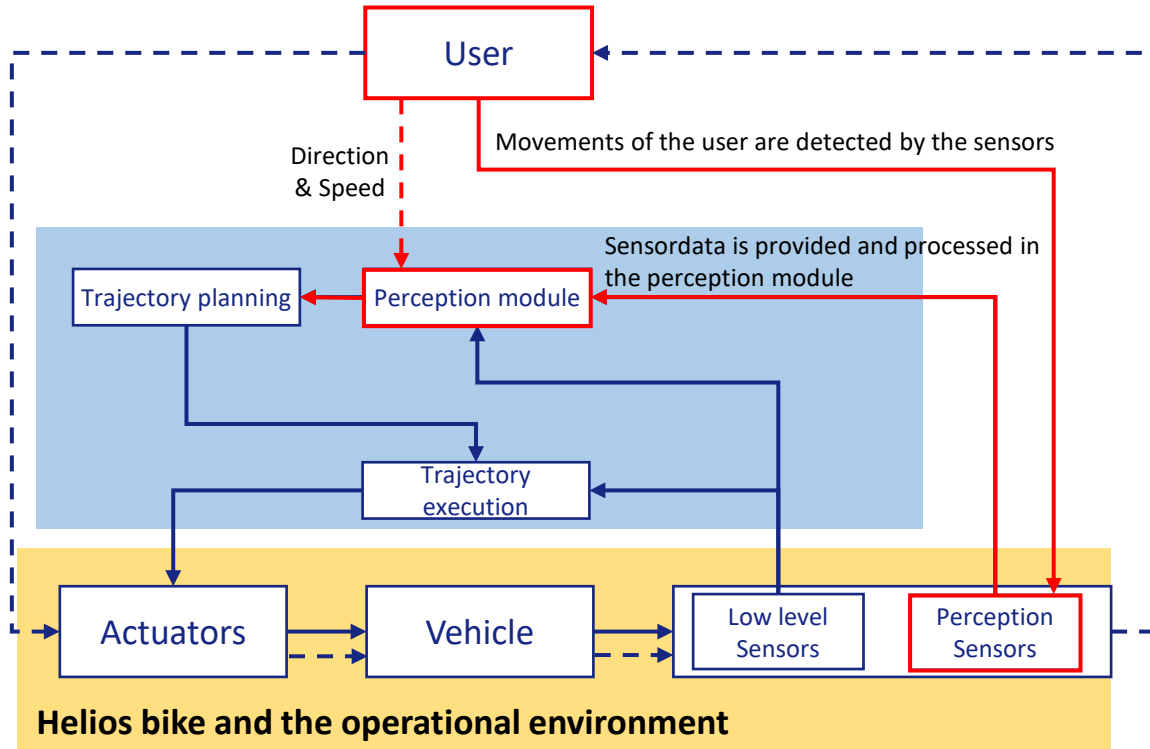
The “right” level of abstraction provides sufficient details at the right levels



Follow-Me

Control of the vehicle is done implicitly via the actions and movements of the user

- **Control actions** are **not directly** provided from the use to the bicycle
- The user **indirectly controls** the vehicle via his movement
- **UCA-Analysis** of the **user** is focused on the **behaviour** and the **decision process**
- **Modelling the perception module** turned out to be a benefit when **analysing UCAs** from the **sensor feedback** and the **control algorithm**

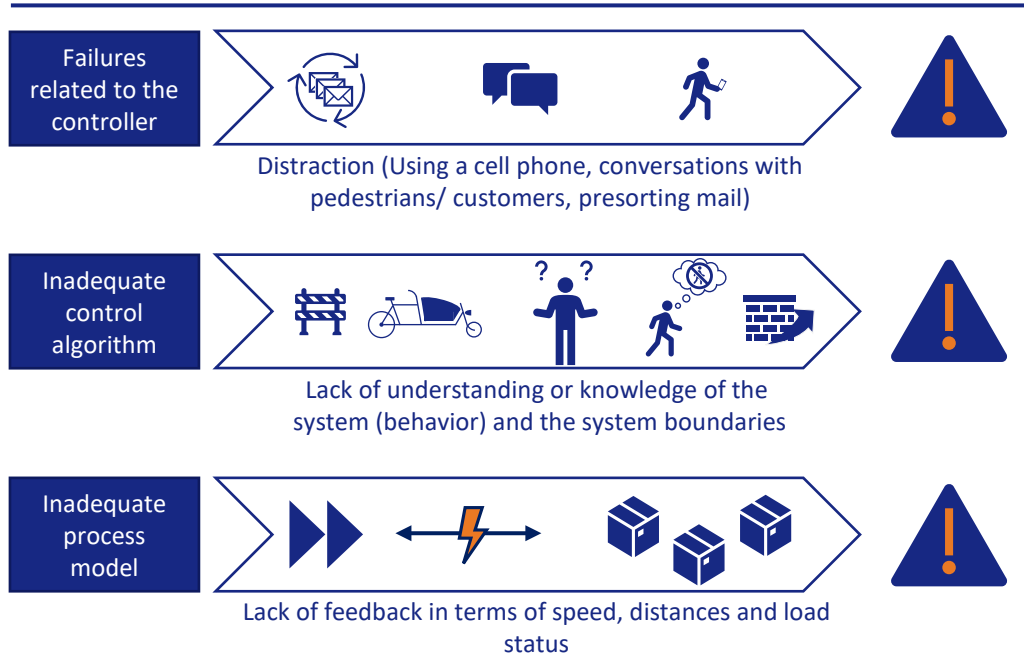


Examples from the UCA analysis worksheet

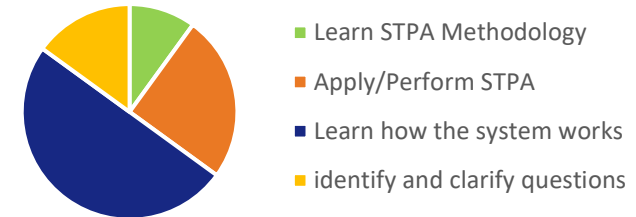
Update column C and K		Unsafe Control Actions						Loss scenarios					
Notes and Disclaimer: If not explicitly mentioned all described UCAs refer to the vehicle in follow me mode.													
Controller	Control Action	Type 1 UCA ID	Type 1 Not providing causes hazard	Type 2 Providing causes hazard	Type 3 Too early, too late, out of order	Type 4 Stopped too soon, applied too long	Applicable for continuous control actions	Comment UCA	Hazard Link	Scenario 1	Scenario 2	Scenario 3	Scenario 4
Direction (Intended path the user is providing by walking in front of the bike → speed and direction)	Deactivate Follow Me Mode		User does not provide the "deactivate follow me" command when he or another person is approaching the bicycle.					This incl. several context situations in which the user might need to approach the bicycle, (e.g. load and detach of cargo, continue ride in manual or pedelec mode etc.)	H1	He does not know about the minimum safety distance and that he needs to deactivate the follow me mode before approaching the bike due to missing or incomplete training / instructions.		User is not familiar with the handling of the device used to provide control actions, e.g. as he does not receive a training or complexity of the device/user interface.	User is not able to estimate the distance correctly.
		UCA 7	User does not provide the "deactivate follow me" command when he is approaching terrain inaccessible to the bicycle.						H3	He does not know about the limitations and restrictions of the bicycle due to insufficient training / instructions.	User tries to intentionally test the limits of the bicycle.	User is distracted and does not recognize the environmental conditions or he forgets to send the signal.	User forget about the limitations as he usually is operating in a environment w/o specific limitations and is operating in a new environment. Initial training was provided some time ago.
	UCA 22			User provides a direction command with more than 8 km/h.			E	Bicycle speed is limited to 8 km/h	H3	User is walking with more than 6km/h as he is not aware about the speed limit due to missing training / instructions.	User is walking with more than 6km/h as he is not able to estimate his speed properly and he does not receive any feedback.		
	UCA 23			User provides a direction command with a curvature which is too sharp while the bike is heavily loaded.			E		H4.1, H3	User is not aware about the capabilities of the bicycle with respect to its behaviour when heavily loaded and the resulting limitations to make sharp turns to missing training / instructions or the information are not well explained.	User tries to intentionally test the limits of the bicycle.		
	UCA 24			User provides a direction command with a sharp curve while he is walking around a corner with concrete walls.					H2, H3	User is not aware about how he needs to walk around a corner in follow me mode due to missing training / instructions or the information are not well explained.	User tries to intentionally test the limits of the bicycle.		

User: UCAs are primarily caused by distraction and missing knowledge about the system

Summarized Results of the User Analysis



Analysis first iteration process



*Evaluation of data using similar categories described by Dr. John Thomas (MIT) in a sample analysis

- 25 Workshops with 1 – 1,5 h each
- 3 participants on average
- Total effort around 100h + incl. preparation and reworking



- Project-related fragmented implementation of the analysis inefficient
- A high number of UCAs was related to L3, recommendation to conduct separate STPA analysis

CONTACT



Stefan Braun
Senior Consultant
s.braun@fsq-experts.com
+49 (0) 151 420 746 75

CONTACT

Managing Directors:
Matthias Größler
Christoph Hauck

Balanstraße 14
81669 München

P +49 (0)89 588 087 570
@ contact@fsq-experts.com
www.fsq-experts.com

