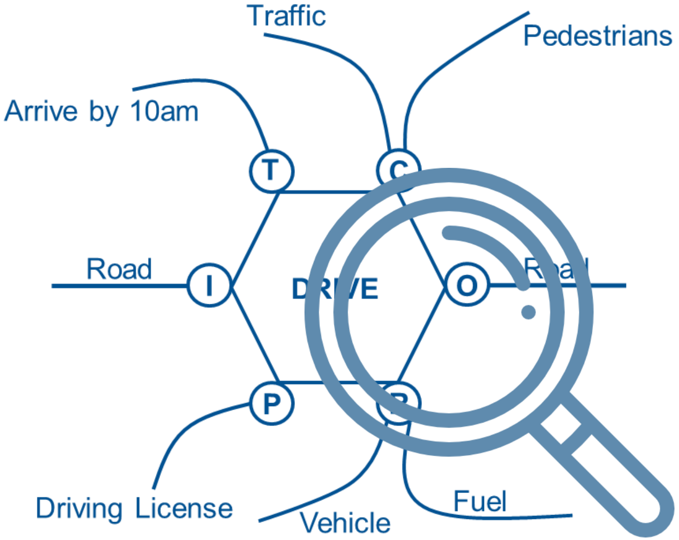
Assessing the reliability and validity of an FRAM model: the case of driving in an overtaking scenario



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FRAMily 2023

Copenhagen, 21th June 2023

Problem & Motivation

FRAM has been **widely used and enhanced methodologically** in a variety of domains for retrospective as well as prospective analyses *Patriarca et al. (2020)*

FRAM has been **progressively evolved** since its starting point in 2004;
the **most recent and promising step** in **understanding socio-technical systems** *(Nemeth, 2013)*

However, **lack of formal testing of the reliability and validity** of FRAM 

findings from the application of FRAM **suffer from an objective evaluation**, making the **research findings questionable**.

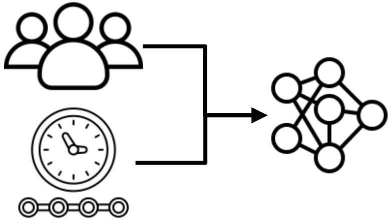
FRAM must prove that it is useful in fulfilling its purpose in their applied domains to **promote its credibility**

development of a framework to demonstrate reliability and validity for an FRAM model

Definitions and understanding

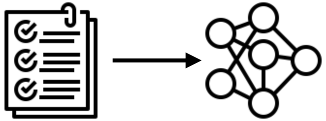
Reliability

Measurement of the stability of the method over time and across analysts. Application results are the **same results if it is used by different people (inter-rater) or at different points in time by the same people (intra-rater)**



Verification

Determination of correct formal implementation of a model dealing with **building the model correctly**



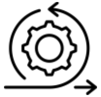
Validation

Determination whether a model can be substituted for the real system for the intended purposes and objectives in the applied domain dealing with **building the right model**

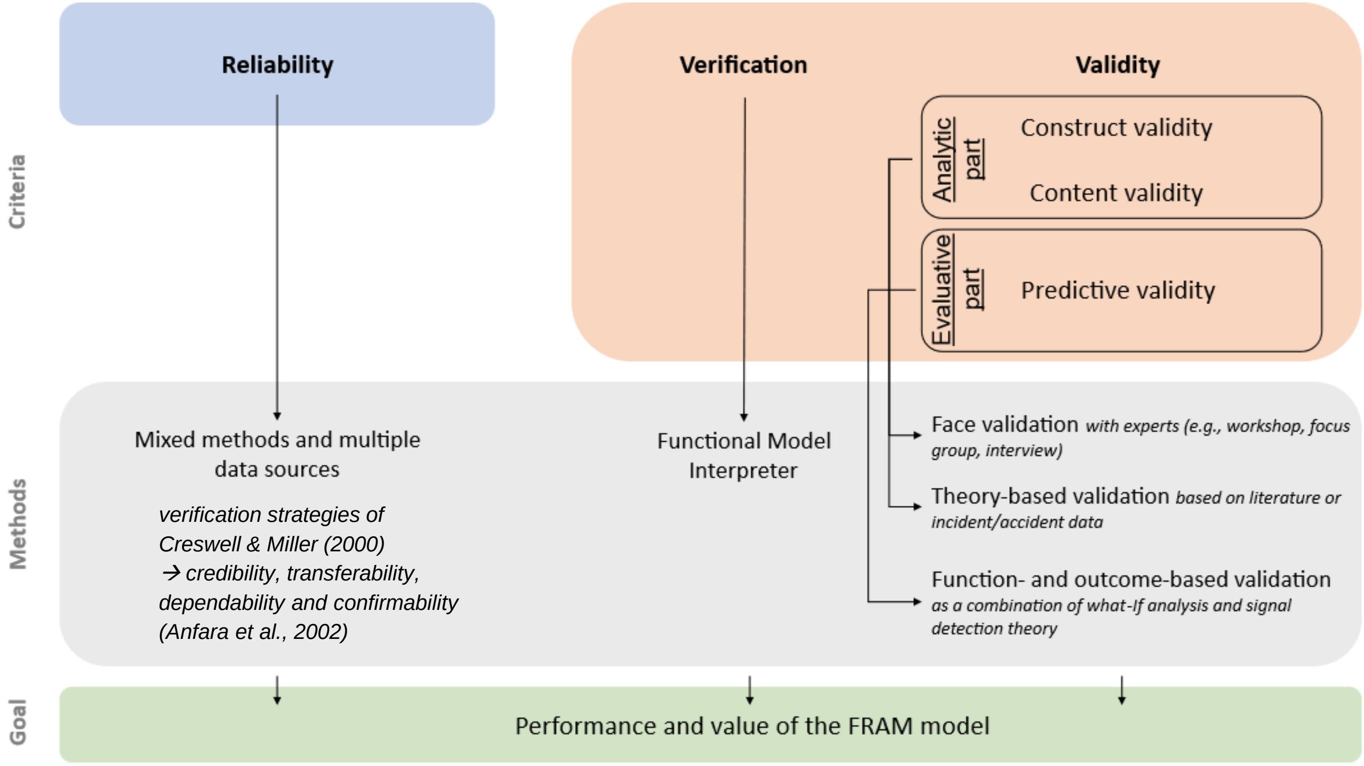
(Balci, 1998; Stanton, 2016)

Definitions and understanding

Nature of validity *(Liebl, 2018)*

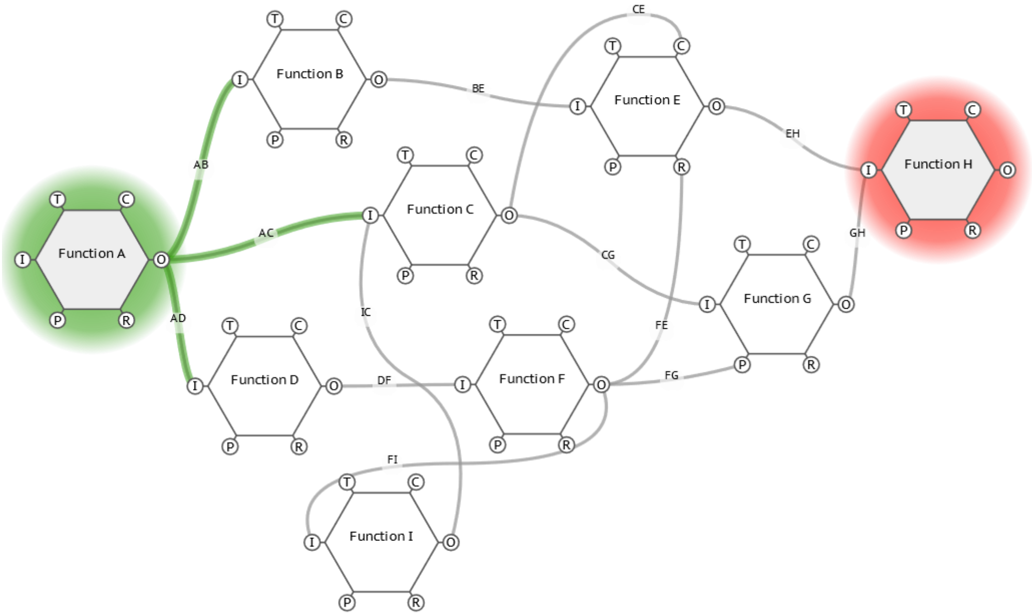
- model-individual 
- gradual 
- result of a negotiation process 
- continuous and iterative 

Reliability and validation framework



(Grabbe et al., 2022)

Function-based validation (what-if analysis)



Upstream function	Couplings	Downstream functions
A ->	AB	-> B
	AC	-> C
	AD	-> D
B ->	BE	-> E
C ->	CE	-> E
	CG	-> G
D ->	DF	-> F
E ->	EH	-> H
F ->	FE	-> E
	FG	-> G
	FI	-> I
G ->	GH	-> H
I ->	IC	-> C

(Grabbe et al., 2022)

check whether the variation in the output of the upstream function actually influences the output of the coupled downstream functions while keeping all other functions constant at the same time → for all direct upstream–downstream couplings of foreground functions in an FRAM model

Outcome-based validation (signal detection theory)

Hits

predicted variability effect in a downstream function's output through the manipulation of its upstream function's output by the FRAM model **and observed variability effect** in a simulator or field test.

Misses

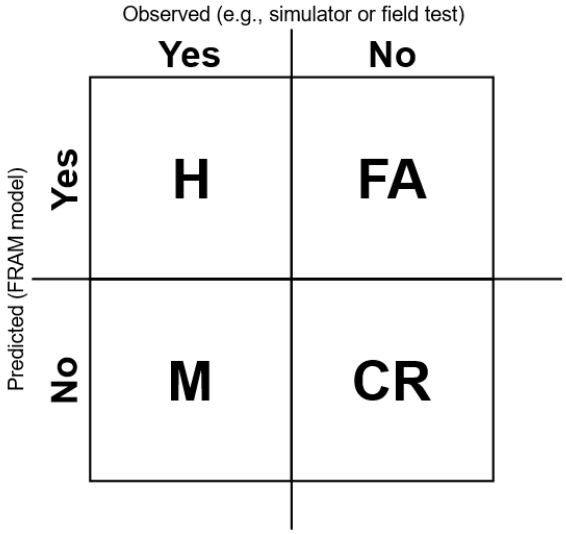
no predicted variability effect in a downstream function's output by the FRAM model **but observed variability effect** in a simulator or field test.

False alarms

predicted variability effect in a downstream function's output by the FRAM model **but no observed variability effect** in a simulator or field test.

Correct rejections

no predicted variability effect in a downstream function's output by the FRAM model **and no observed variability effect** in a simulator or field test.



(Grabbe et al., 2022; Stanton, 2016)

Measures and analysis

Dependent variables:
performance variability outputs of several subjective and objective functions

Timing

1 2 3 4 5 6 7

Too early On time Too late Not at all

Precision

1 2 3 4 5 6 7

Precise Acceptable Imprecise

- Speed
- Lane deviation
- Distance between cars
- …

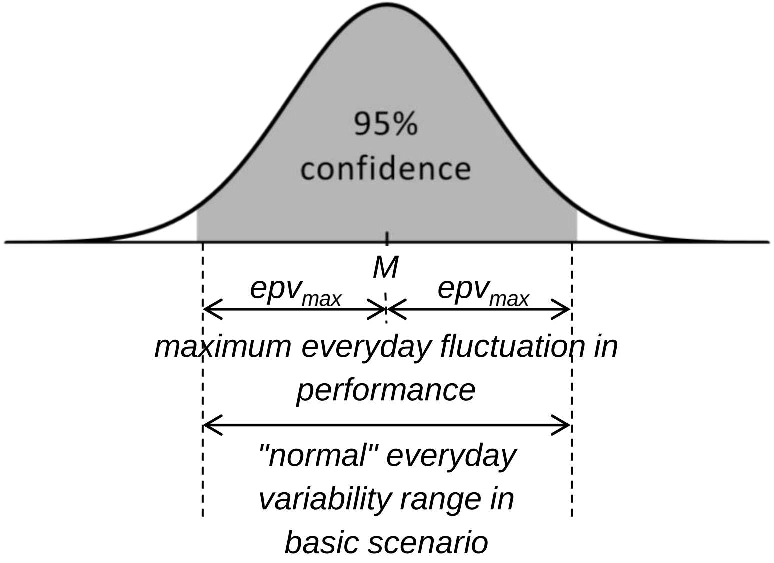
e.g., the average distance between EV and LV in the period, where the straight begins and the driver of EV starts to swerve, indicated by the left activated indicator or the steering angle

Manipulated function	Analysed functions of EV	Type of rating	SDT event category
Driving free LV	check vehicles in front of LV	Subjective	H/FA
	check LV is not about to change speed		H/FA
	gauge future driving actions of LV		H/FA
	check LV is not indicating or about to turn		H/FA
	maintain an adequate view of the road ahead		H/FA
	evaluate reasonableness for overtaking		H/FA
	assess the situation to enter safely		H/FA
	judge LV's relative speed to OV		H/FA
	judge LV's speed		H/FA
	judge available passing time		H/FA
	determine pass can be completed		H/FA
	observe road behind		M/CR
	check for safe distance to merge		M/CR
	judge first OV's speed		M/CR
	judge distance from first OV		M/CR
	maintain headway separation	Objective	H/FA
	keep in lane		H/FA
	position car to the right		H/FA
	position car to the left		H/FA
	reduce headway from normal following		H/FA
	avoid tailgating and intimidating LV		H/FA
	adjust speed to that of LV		H/FA
	adopt overtaking position		H/FA
	swerve completely to the oncoming lane		H/FA
	accelerate LV decisively		H/FA
	merge back into starting lane		H/FA
	merge progressively into starting lane		H/FA

(Grabbe et al., 2022)

Measures and analysis

- one-sided one-sample t-tests with a p-value of 5%



Function: e.g. maintain headway separation

ID	Performance value Scenario Baseline	Performance value Scenario Testing	∆Performance value	epv_{max}
1	20m	24m	4m	4m
2	15m	10m	5m	
3	17m	11m	6m	
…	…	…	…	

If mean∆Performance value > epv_{max} → H/M
If mean∆Performance value < epv_{max} → FA/CR

Measures and analysis

1) $\text{Accuracy} = \frac{\text{H} + \text{CR}}{\text{H} + \text{FA} + \text{M} + \text{CR}}$

2) $\text{HR} = \frac{\text{H}}{\text{H} + \text{M}}$

3) $\text{CRR} = \frac{\text{CR}}{\text{FA} + \text{CR}}$

Predictive validity level	**Percentage of accuracy, HR, and CRR**
Poor	0%
Slight	>0–20%
Fair	21–40%
Moderate	41–60%
Substantial	61–80%
Almost perfect	81–100%

(Grabbe et al., 2022; Olsen, 2013)

Limitations

- **impossible to validate the whole FRAM model** (large and complex FRAM model) --> only a few functions and their expected, as well as unexpected effects can be examined

- when manipulating one function, it is **difficult to actually keep all the remaining functions constant** that were supposed to be constant, since the type of manipulation measure can potentially affect the performance of other functions → **interaction effects**, whereby observed effects can no longer be fully attributed to the manipulated function

- it might be **difficult to find a targeted manipulation measure** for each function in the model, e.g., for cognitive functions, since either no targeted manipulation is possible, or several functions would be manipulated at the same time

- the **extent and manner in which a manipulation must be carried** out to achieve the desired effect are generally unclear

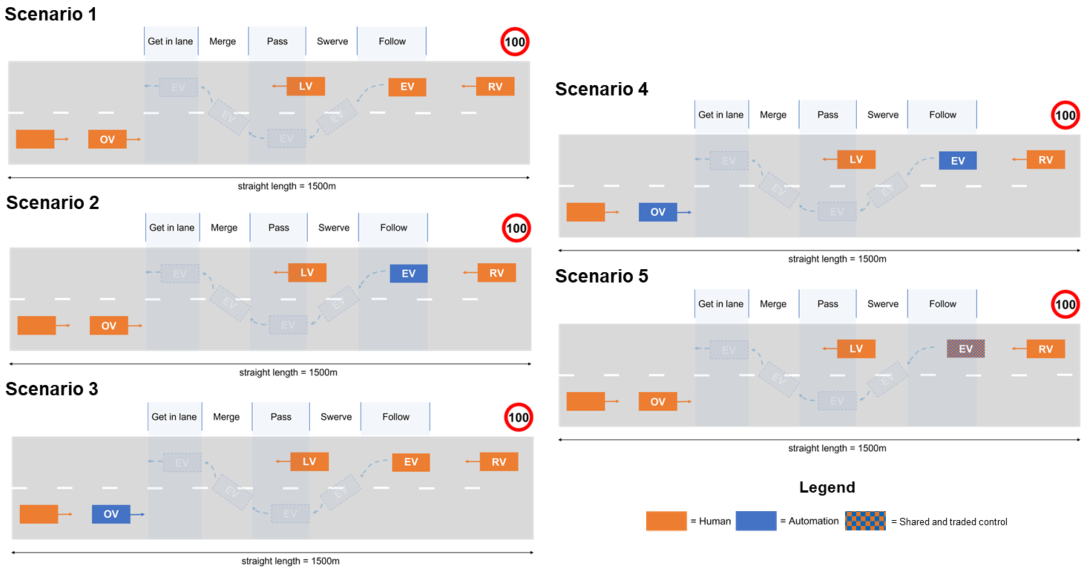
- the **performance variability of a downstream function may only change when several upstream inputs are varied instead of just one manipulated function**. Consequently, all what-if combinations would have to be considered to be able to represent the complexity, which is simply impractical

Only function-based validation

sensitivity analysis with deliberate and controlled variations in the model as a falsification approach by checking the response mode of the model for plausibility in order to prove the model's credibility.

changing automation of different agents and activities/functions in the FRAM model

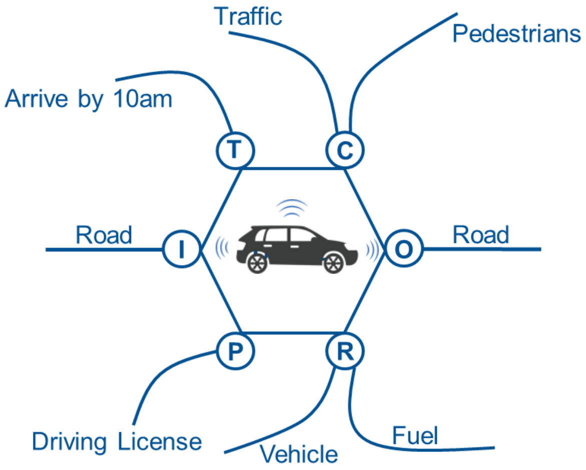
→ Use of semi-quantitative metrics, e.g., *Grabbe et al. (2021); Hirose & Sawaragi (2020); Patriarca et al. (2017)*



Key messages

- The **scope and objective** (i.e., use of FRAM) **determine the validity type** and its required methods
- FRAM model has at least a **partly tautological character** meaning that model results are only **partly falsifiable** for two reasons: **interacting variables** (i.e., functions) difficult to prove empirically, and **no measurability of single, absolute outputs but multiple relative outputs**.
- FRAM model can **rather be calibrated than validated**

Research work



→ PhD thesis is going to be published in spring 2024!

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Questions & Answers

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