Optimal parameter estimation problem for the vehicle dynamics. The optimization tries to find a set of model parameters, that best explain/reproduce the experiment data.

$$
\begin{aligned}
\underset{\boldsymbol{x}_k^j, \boldsymbol{p}}{\text{minimize}} \quad & \sum_{j=1}^{n_{experiments}} \sum_{k=1}^{n_{timesteps}} E(\boldsymbol{x}_k^j - \hat{\boldsymbol{x}}_k^j) \\
\text{subject to} \quad & \boldsymbol{x}_{k+1}^j = \boldsymbol{x}_k^j + \Delta t \cdot f(\boldsymbol{x}_k^j, \hat{\boldsymbol{u}}_k^j, \boldsymbol{p}) \\
& k = 1..(n_{timesteps} - 1) \\
& j = 1..n_{experiments}
\end{aligned}
$$

$\hat{\boldsymbol{x}}_k^j$	Measured States
$\hat{\boldsymbol{u}}_k^j$	Measured Inputs
f	Vehicle dynamics model
$\boldsymbol{p}$	Model parameters
Δt	Constant timestep $0.02s$
E	Error penalty function

Error penalty E: Weighted quadratic error with model specific extensions. The yaw error function has a period of 2π, so that a full rotation does not count as an error. This is done using $\sin(\Delta\psi/2)$.

Delays: This kind of optimization problem is not well suited for identifying the delay times (Totzeiten). The delays are solved in an outer loop. The delay is guessed/assumed and the measurement data is modified by appropriately shifting it in the time index k. This optimization problem is solved many times for combinations of delay times. The delays that create the lowest objective value are taken as the solution.