Towards multi-objective optimization of a rail vehicle

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General targets

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To contribute with new knowledge to increase railway vehicle (RwV) costefficiency of operation with restrictions on safety and comfort

- To formulate and solve several multi-objective optimization problems for the bogie systems

  Engineering, Mathematical and Computational (EMC)-models

  Quality factors

  Constraints

  Algorithms

- To identify the optimal properties of railway bogie systems.

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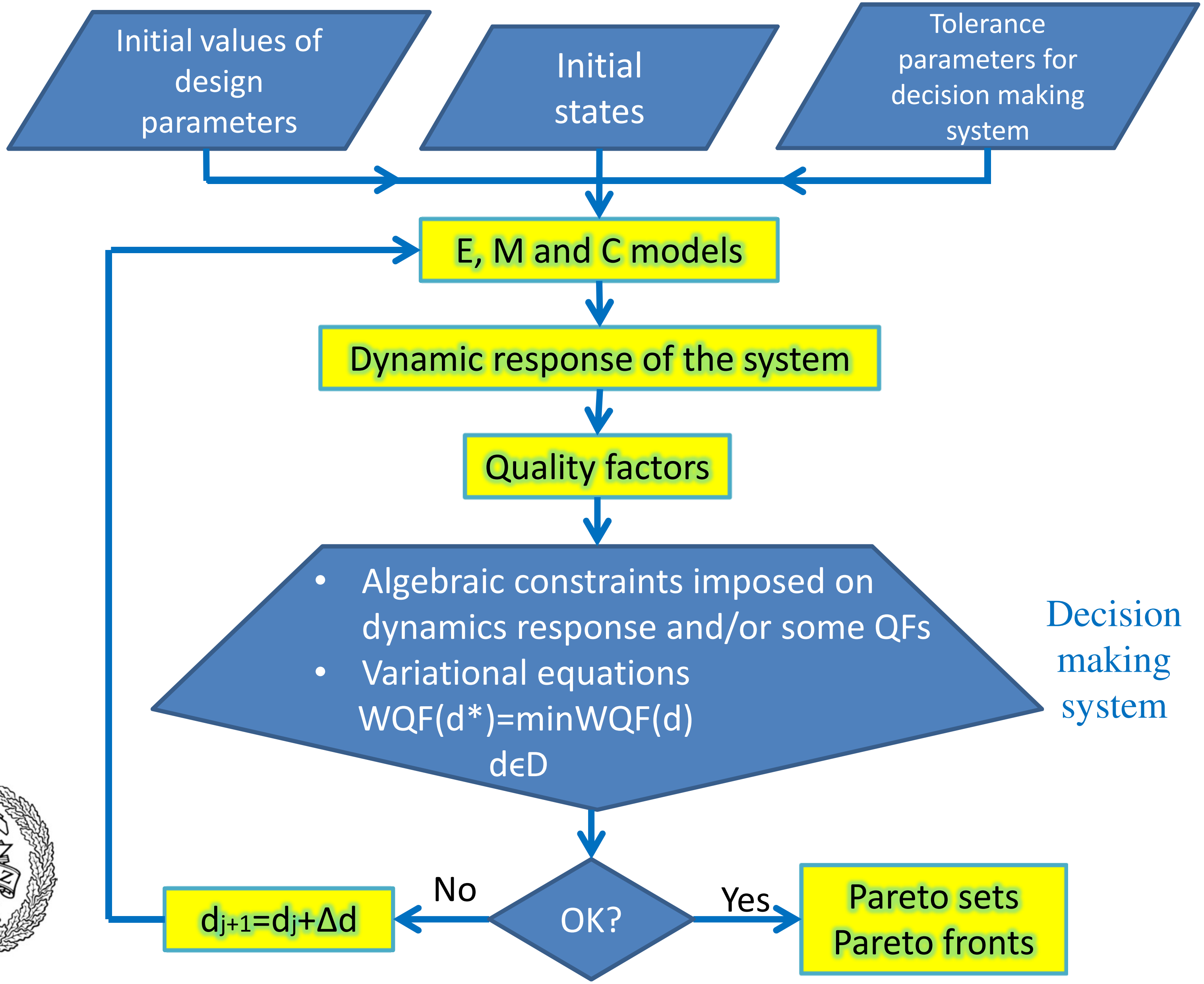
Pareto optimization



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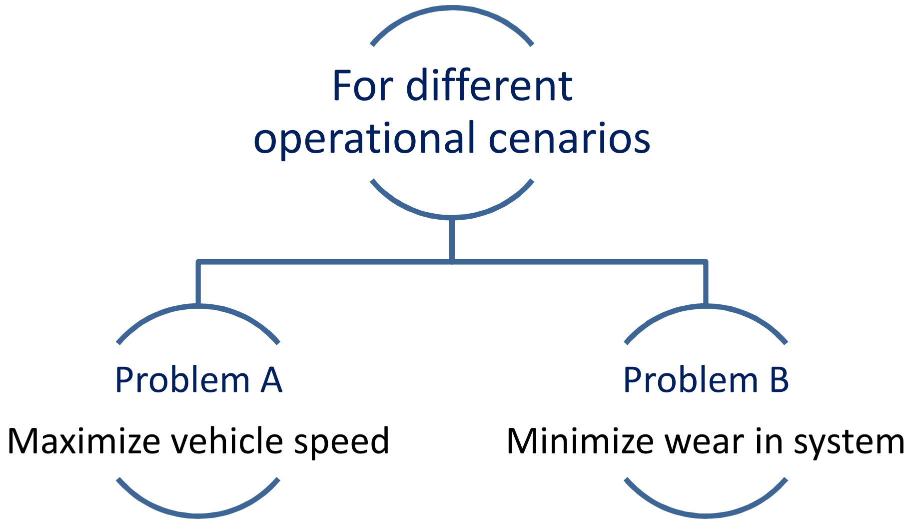

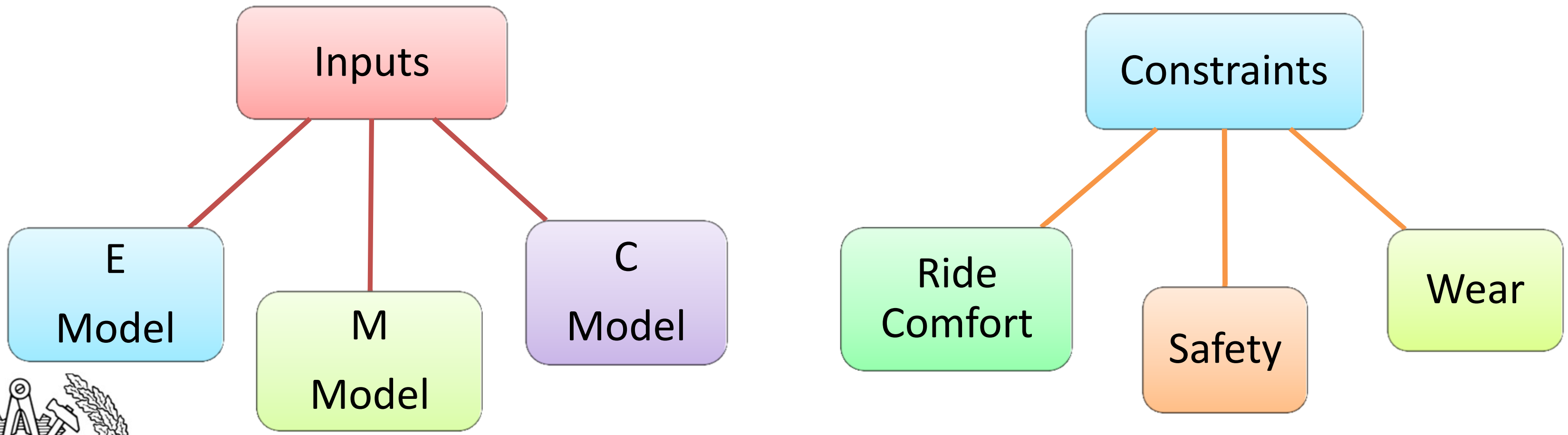

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An example of problem A

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Inputs:

- EMC-models
- Initial states
- Structural parameters
- System dynamics parameters
- Track irregularities

Tasks:

- Max speed of RWV operation
- Optimized vector of bogie design variables
- Dynamic response of RWV

$$F_C^*(d^*, V^*) \leq F_C^{\max}$$
$$F_S^*(d^*, V^*) \leq F_S^{\max}$$
$$F_W^*(d^*, V^*) \leq F_W^{\max}$$

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An example of problem B

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Inputs:

- EMC-models
- Initial states
- Structural parameters
- System dynamics parameters
- Track irregularities

Tasks:

- Max speed and Min wear
- Optimized vector of bogie design variables
- Dynamic response of RWV

$$\min F_W(.) = F_W^*(d_W^*, V_W^*)$$
$$F_S^*(d_W^*, T_W^*) \leq F_S^{\max}$$
$$F_C^*(d_W^*, T_W^*) \leq F_C^{\max}$$

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Ride comfort

$$\widehat{a}^{i}_{rms} = \sqrt{\frac{1}{t_f - t_0}\int_{t_0}^{t_f}(a^i(t))^2 dt}$$

- Wertungszahl (Wz)
- EN 12299

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Vehicle safety

- Risk of derailment

$$\hat{r}_1^i(t) = \frac{Lateral\ force}{Vertical\ force}\ ,\ Over\ each\ wheel$$

Running stability

- Critical hunting speed
- EN 14363
- Track shift force

$$S^i(t) = R_y^{i_{left}} - R_y^{i_{right}}$$

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Economy

Wear analysis

$$T_\gamma^i = R_{x'}^i \xi_{x'}^i + R_{y'}^i \xi_{y'}^i$$

$$F_{W1} = \sqrt{\frac{1}{t_f - t_0} \int_{t_0}^{t_1} \frac{1}{2n} \sum_{i=1}^{2n} \left(T_\gamma^i\right)^2 dt}$$

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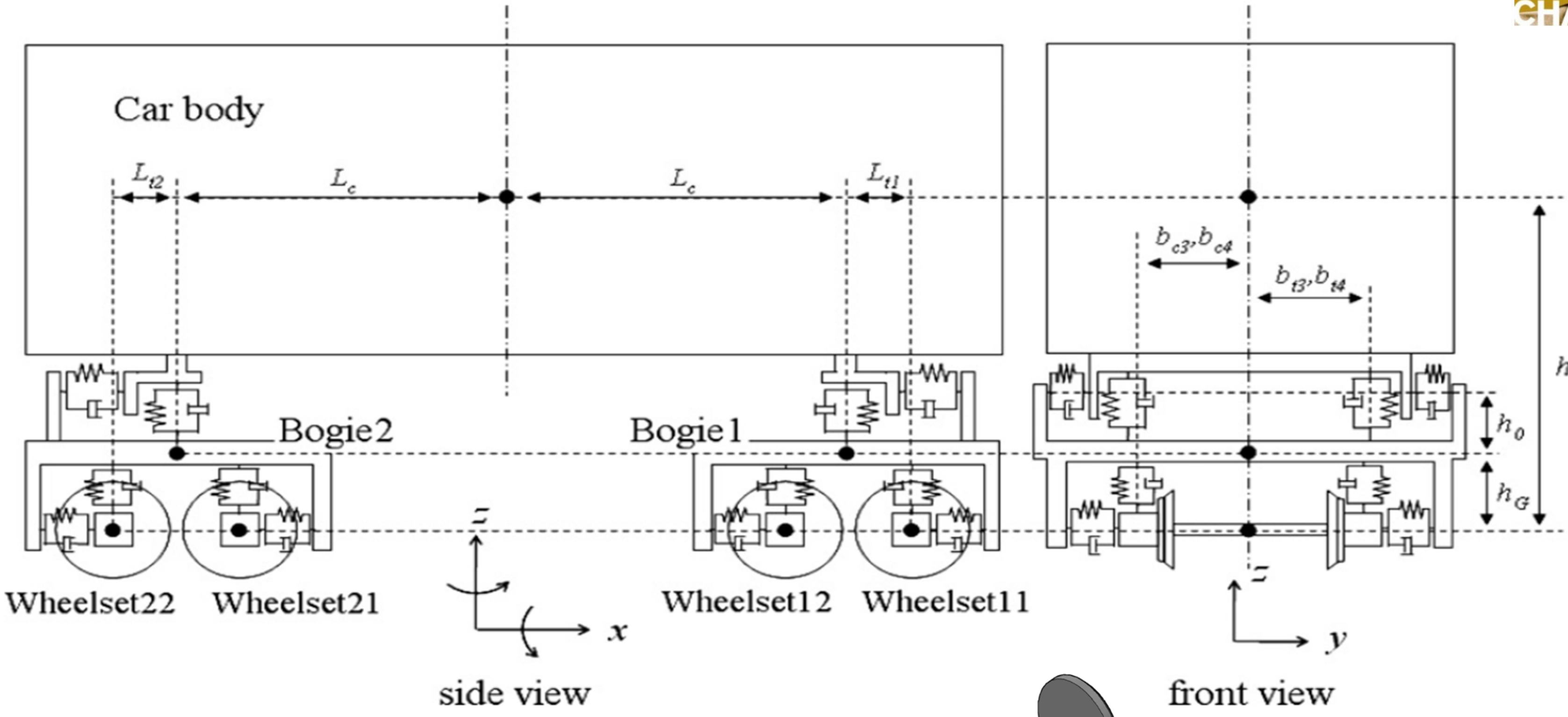
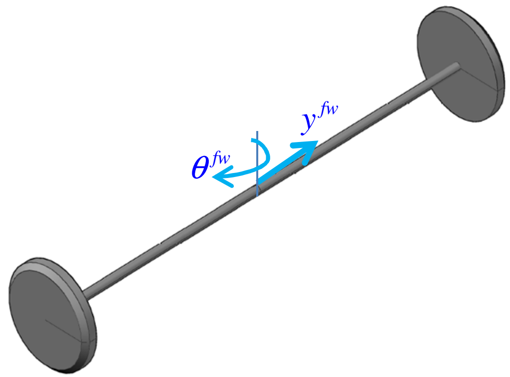
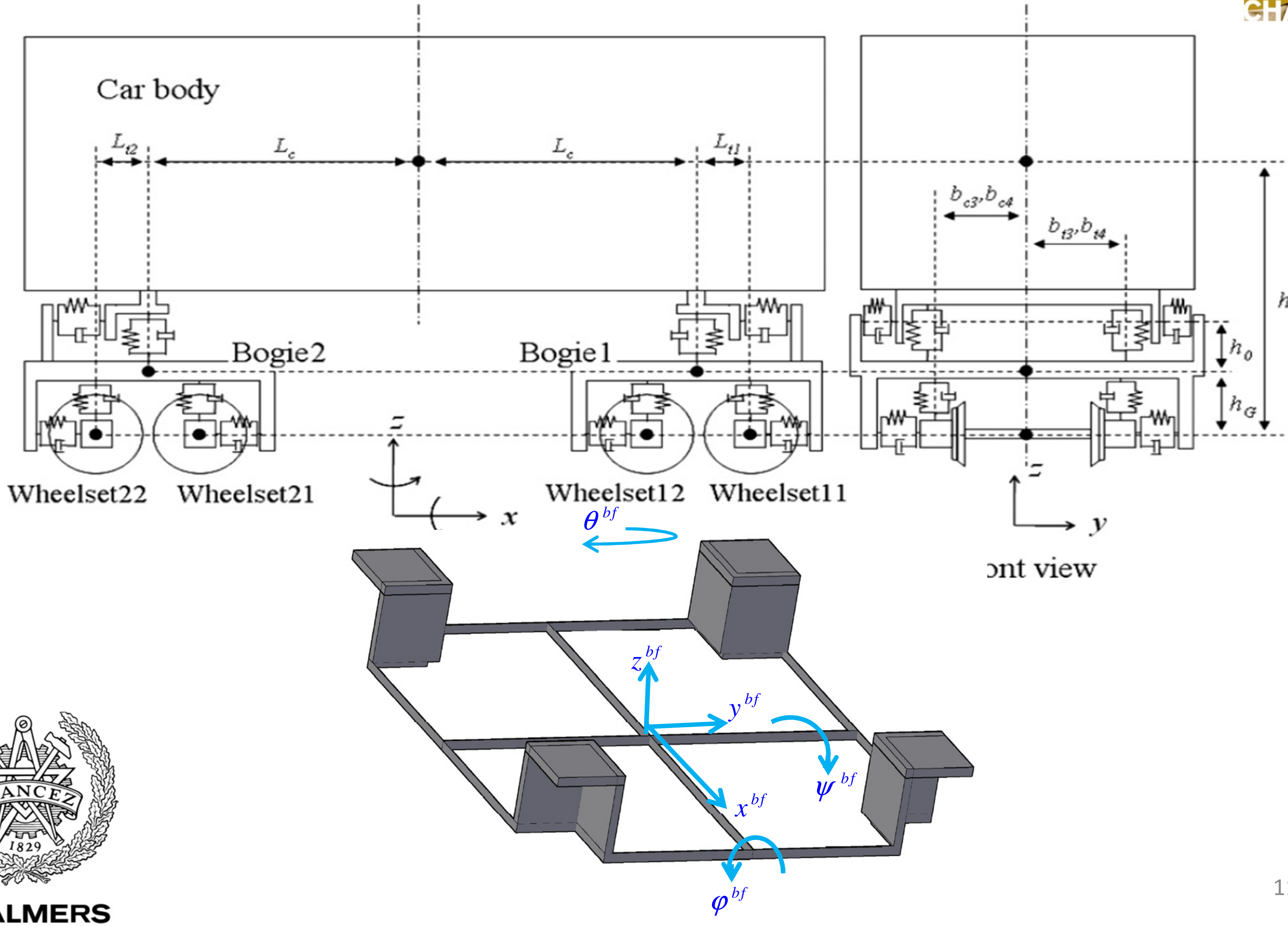
26 DOF one car RwV Model





26 DOF one car RwV Model



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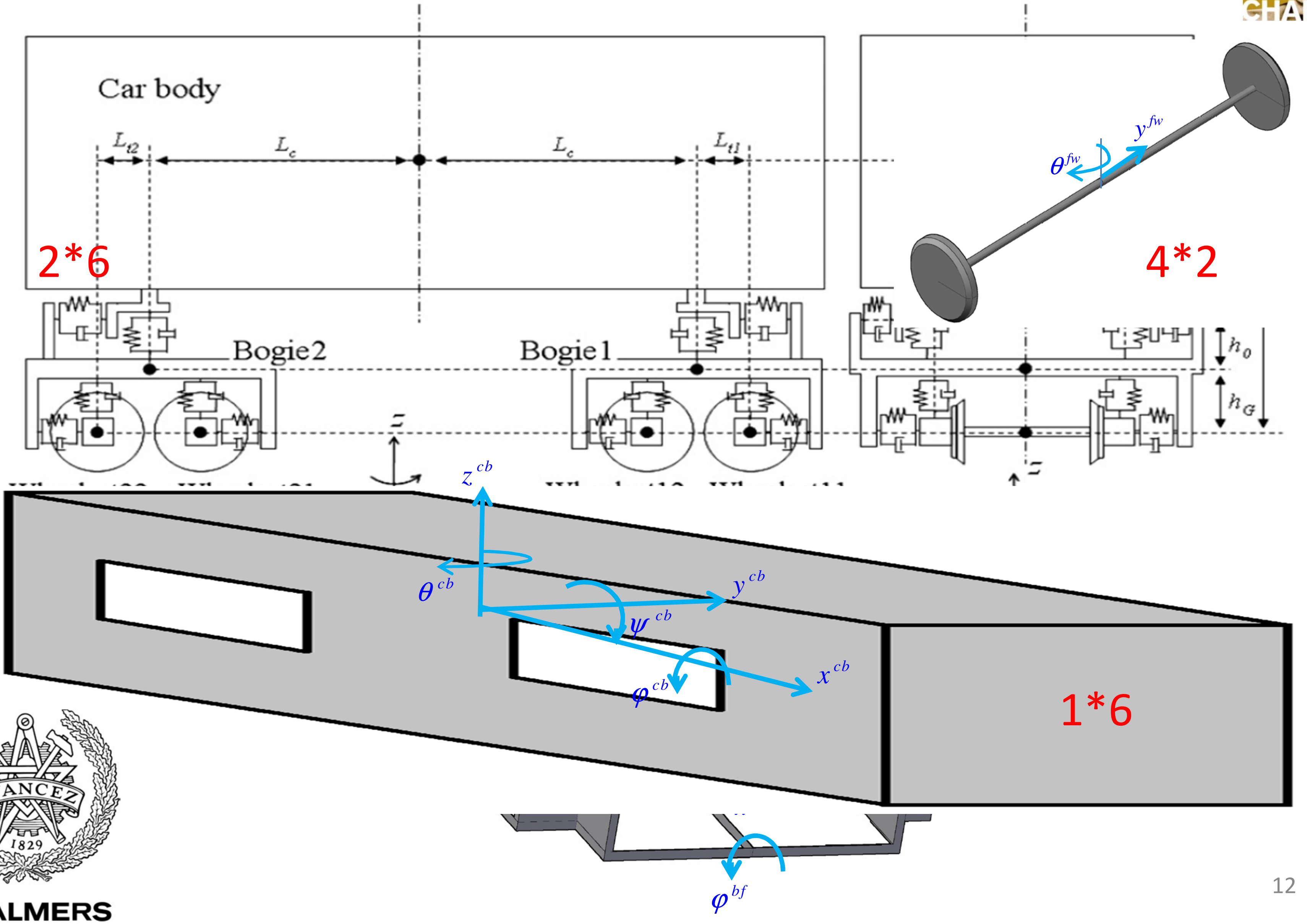
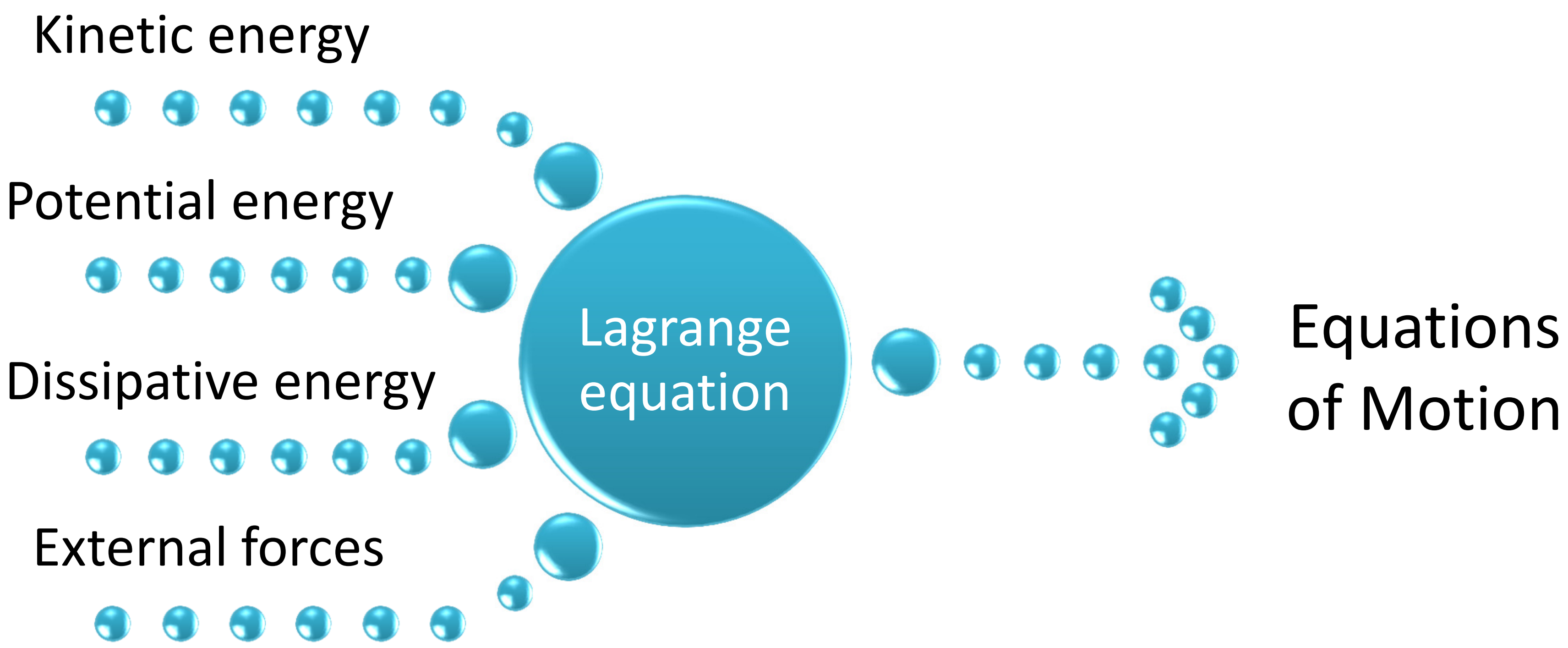
26 DOF one car RwV Model



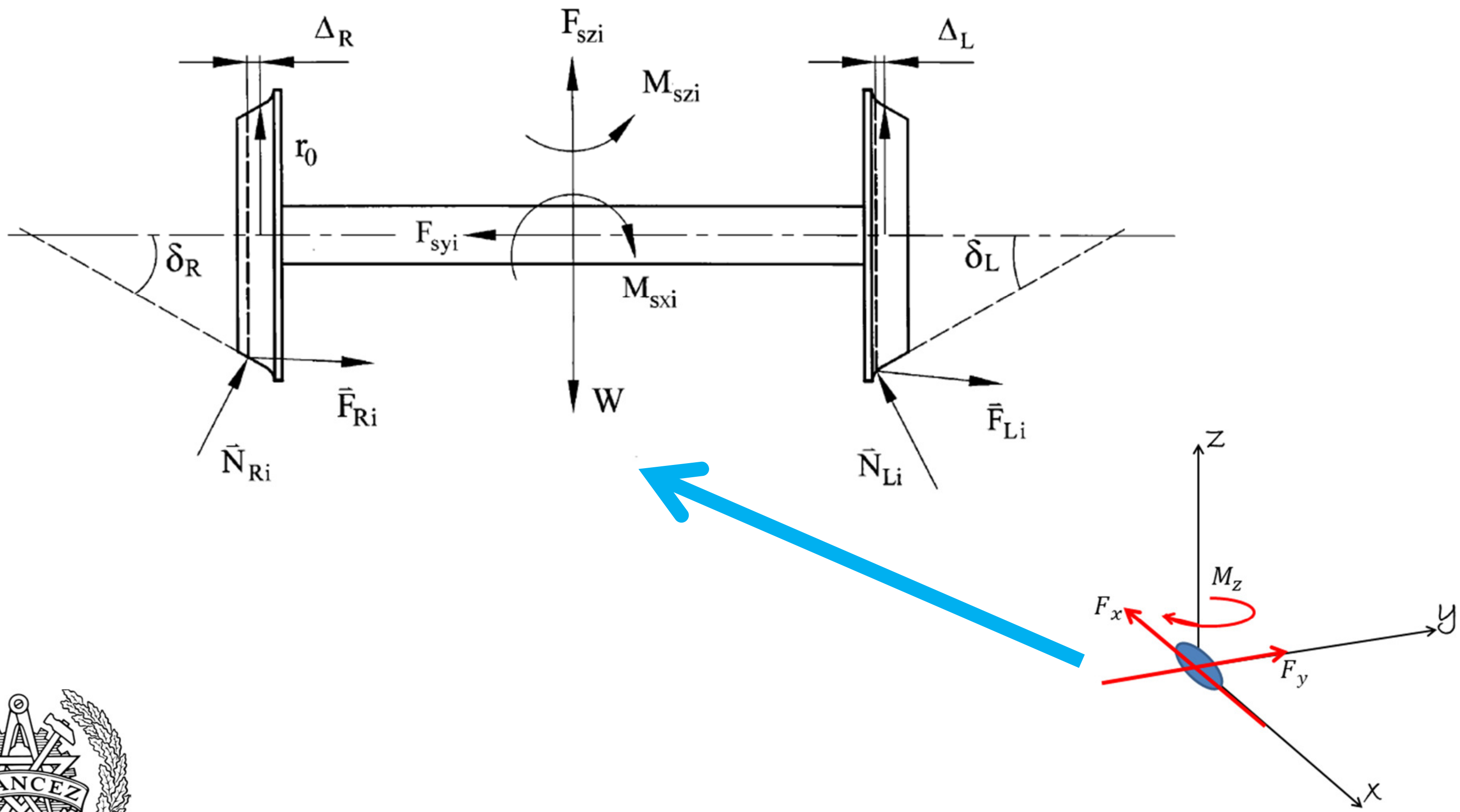
Mathematical model



Contact theory

- Linear Kalker
- Vermeluen-Johnson
- Simplified nonlinear Kalker’s theory (fastsim)

External forces



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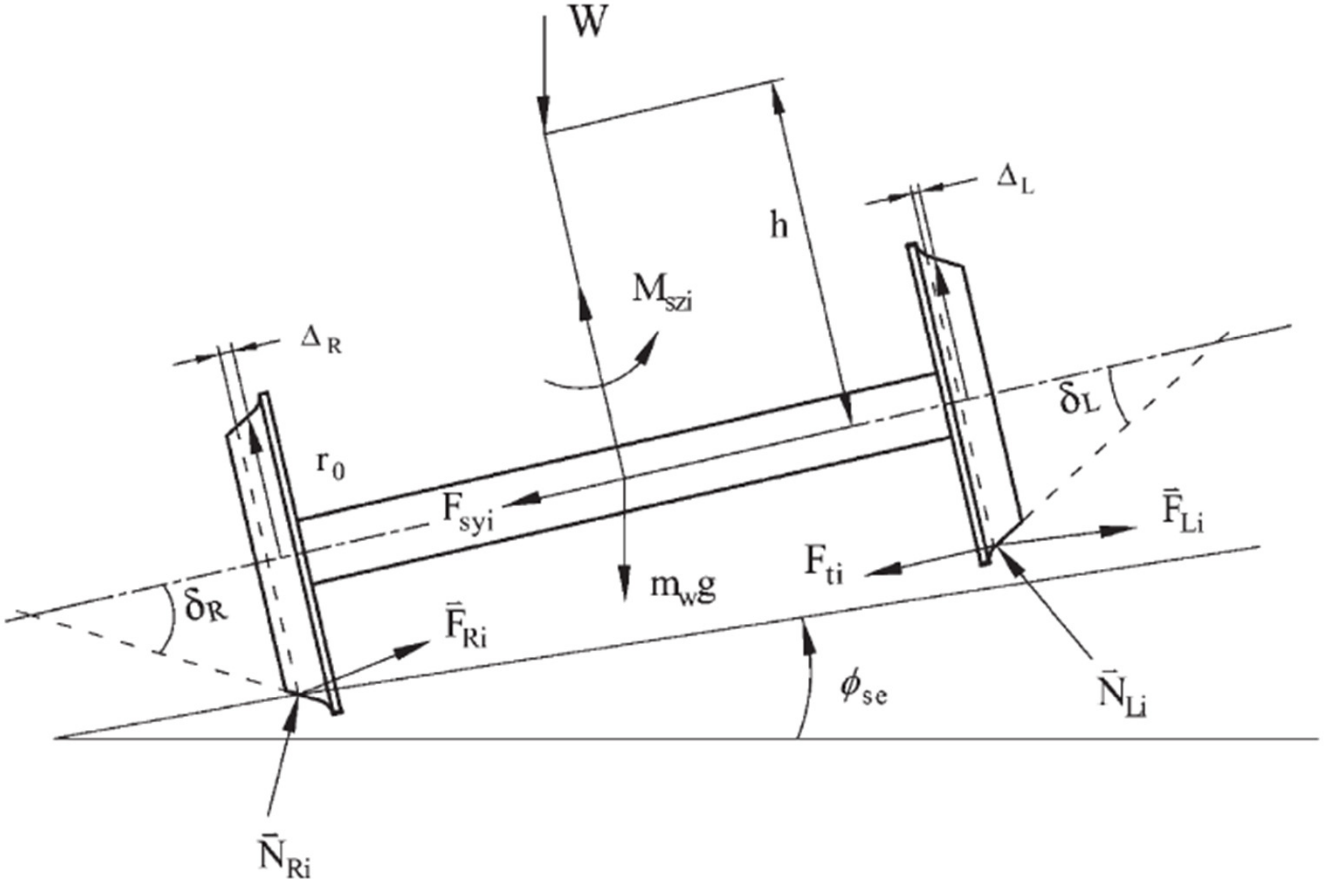
One car train on tangent and curved tracks



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Track irregularities

$$u(x) = \sqrt{2} \sum_{n=0}^{N-1} a_n \cos(\Omega_n x + \varphi_n),$$

$$a_0 = 0, \quad a_1 = \sqrt{\left(\frac{\Phi(\Delta\Omega)}{2\pi} + \frac{\Phi(0)}{3\pi}\right)\Delta\Omega}, \quad a_2 = \sqrt{\left(\frac{\Phi(2\Delta\Omega)}{2\pi} + \frac{\Phi(0)}{12\pi}\right)\Delta\Omega},$$

$$\text{and} \quad a_n = \sqrt{\frac{\Phi(\Omega_n)}{2\pi}\Delta\Omega}, \quad \text{for } n = 3, 4, \ldots, N-1.$$

$$\Phi(\Omega) = A \frac{\Omega_c^2}{(\Omega_r^2 + \Omega^2)(\Omega_c^2 + \Omega^2)},$$

$$\Omega_c = 0.8246\,\text{rad/m} \quad \text{and} \quad \Omega_r = 0.0206\,\text{rad/m},$$

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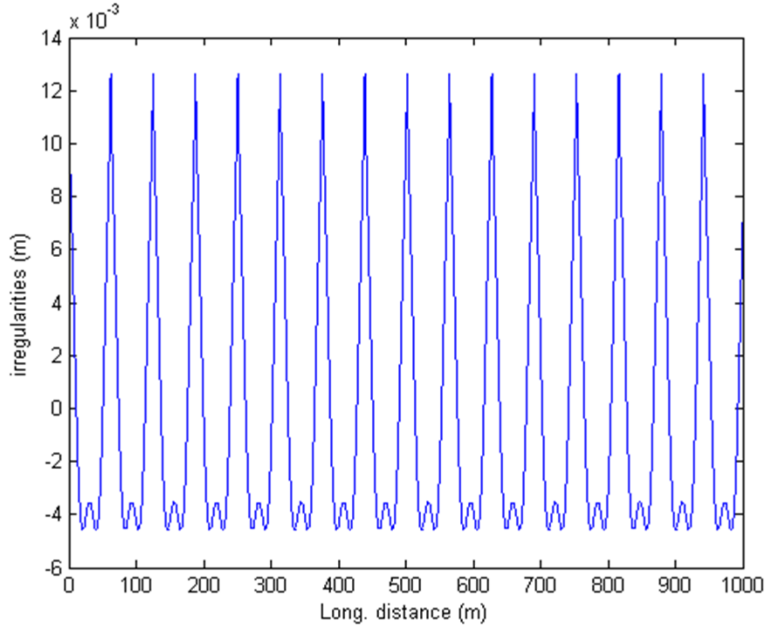
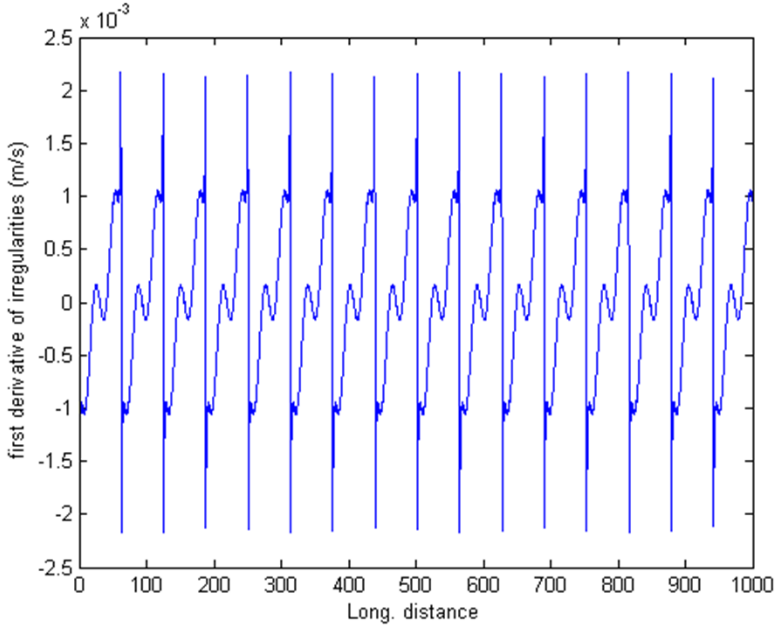
Track irregularities





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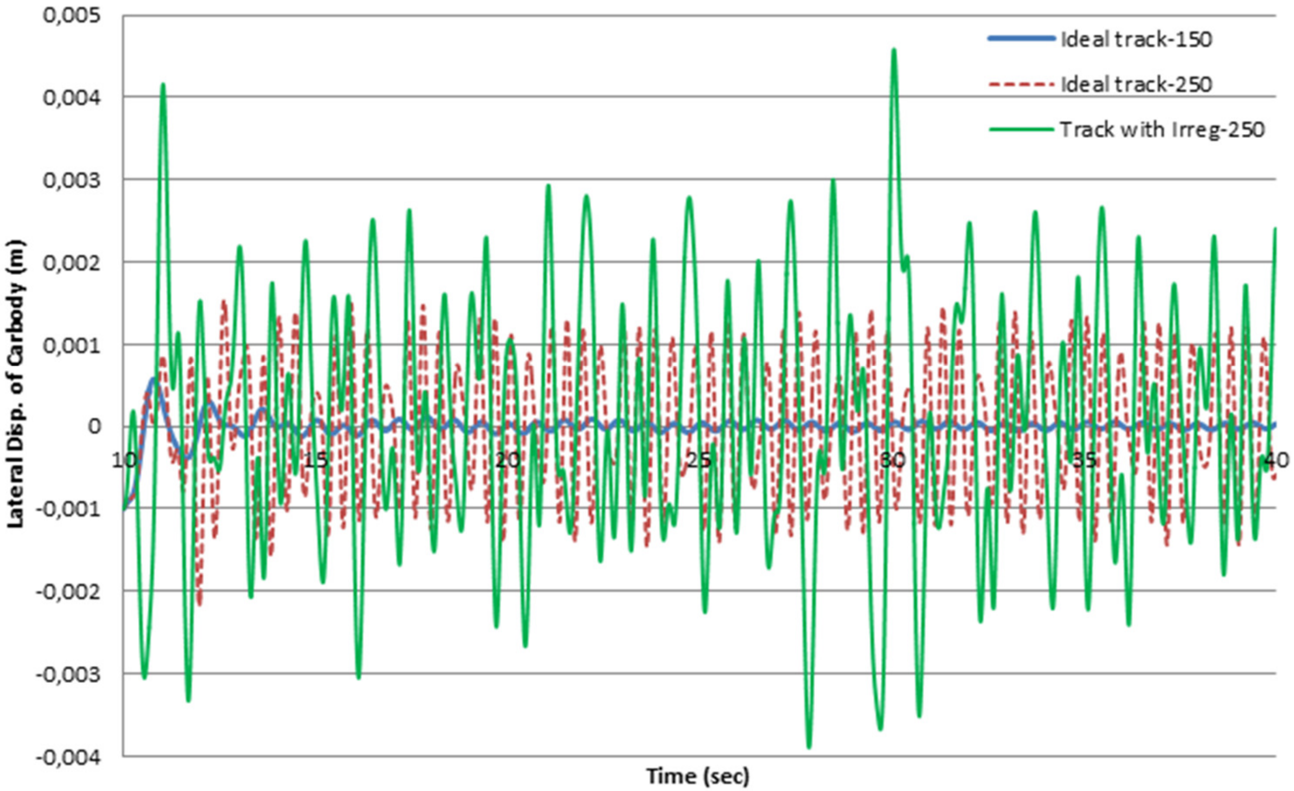
Lateral responses of the carbody with in-service parameters on a tangent track



Comfort evaluation for different operational scenarios and damping parameters (in-service; best comfort; Optimized w.r.t. S & C)

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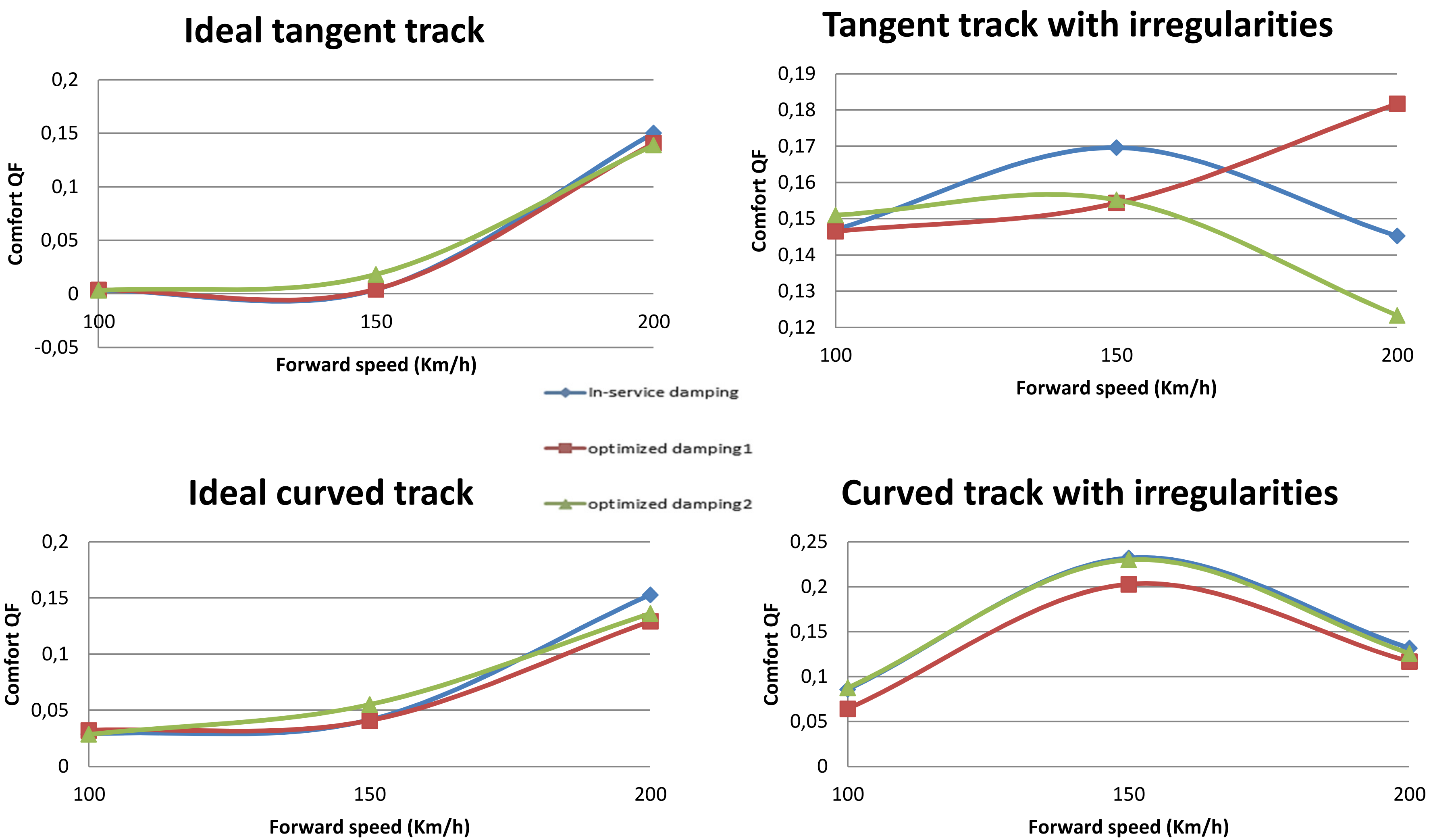

Safety evaluation for different operational scenarios and damping parameters
(in-service; best safety; Optimized w.r.t. S & C)

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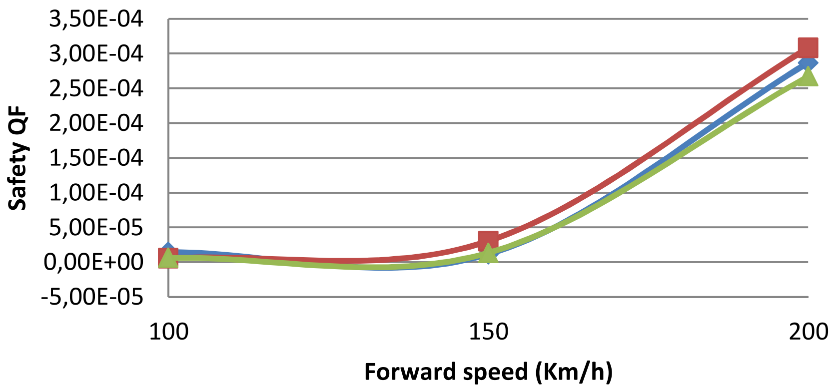
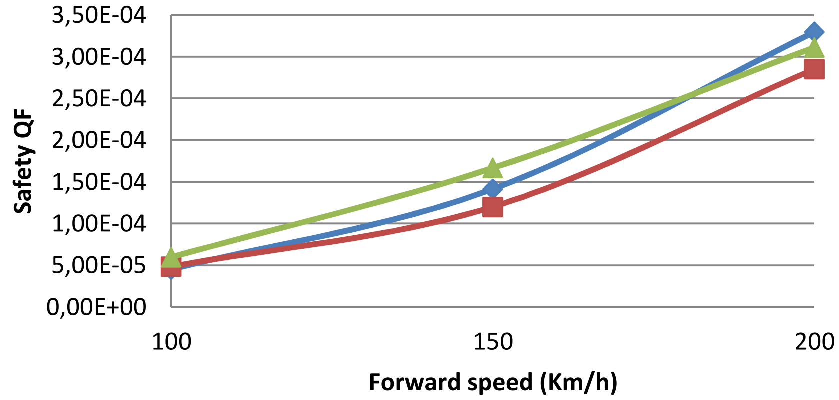
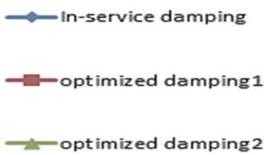
Ideal tangent track

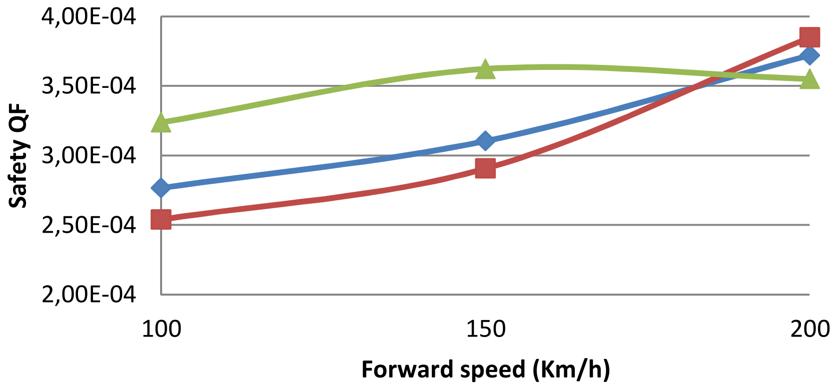


Tangent track with irregularities

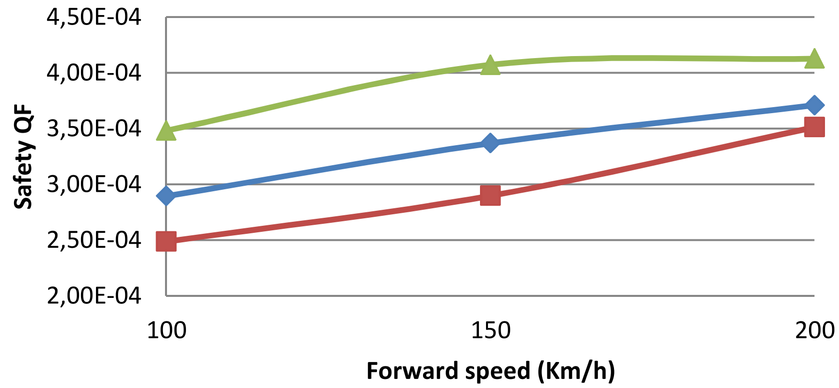




Ideal curved track



Curved track with irregularities



Wear evaluation for different operational scenarios and damping parameters (in-service; Optimized w.r.t. S & C)

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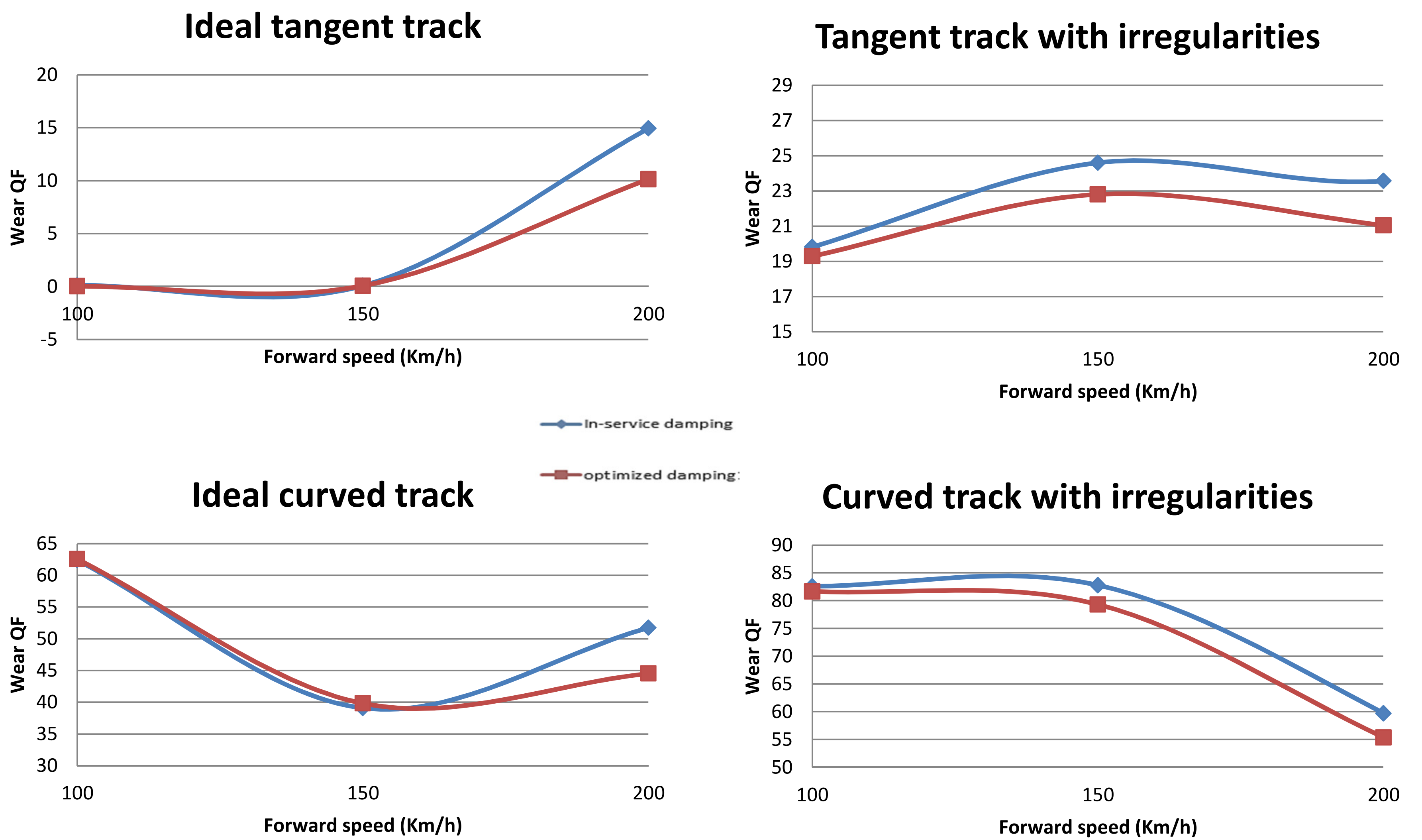

Conclusion and future plans

- Find E,M and C models most suitable for multi-objective optimization of railway vehicle

  26 DOF EMC models of one-car railway vehicle ???

  Propose a reliable test sample model for validation

- Objective functions
- Operational scenarious
- Dynamics and sensitivity analysis
- Design parameters for optimization
- Efficient algorithms for multi-objective optimization of bogie system
- Examine different control strategies and components
- Validate the results with computer simulations and experiment

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Thank You for Your Attention!