Design & Specification of the Track Superstructure based on a Modeling Approach

Thoughts and perspectives…

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Introduction

Why is it necessary for Banedanmark to use a modeling approach?

- The past 5-10 years has meant a massive investment and reinvestment in the Danish railway infrastructure
- The projects are very complex
- Innovative solutions have to be found to complex problems
  - Solutions are often non-trivial
- Often it is necessary to put a lot of efforts in the preliminary phases of the project to determine the correct solution
  - This requires theoretical and practical considerations

Introduction

Examples of projects

- **Copenhagen – Ringsted Project**
  - Transition zones over underpasses
  - S&C Design
- **Fehmarn Belt connection**
  - Transition zones over underpasses
- **Upgrading of Regional Lines**
  - Transition zones to level crossings
  - Turnouts with contra-flexture curves

Example

Transition zones between ballasted and ballast-less track

- Transition zones could be optimized
- The future design that Banedanmark wanted, needed to include best practice considerations
  - The possible different solutions needed to be compared to one another
  - Lifecycle costs shall be considered

Example

Transition zones between ballasted and ballast-less track

- In order to objectively compare the different proposed solutions to one another a modeling based approach was selected
  - Multi-Body Method Models (MBS) and Finite Element Method models (FEM) models were selected
    - It is possible to simulate various possible complex cases/proposed solutions to one another and get the same output information

MBS and FEM models are used as decision support tools!

MBS and FEM models

Strengths and weaknesses

MBS model

- Quick calculation time
- Can be used to simulate the different vehicle types and running properties such as axel load and speed
- Can be difficult to simulate the super- and substructure layers
- Results such as acceleration and displacements can easily comprehended

FEM Model

- Long calculation times
- It can be difficult to simulate vehicle types and running properties
- Easy to simulate the super- and substructure layers
- Can be accurately used to determine more complicated things such as ballast settlement and stresses in superstructure components

MBS and FEM can be linked to one another utilizing the strength from both models

The general approach

Select design cases
- Usually based on a benchmarking of different design solutions from other railway infrastructure managers
  - "Do nothing" (Current) solution
  - Design case 1
  - Design case 2
  - Design case...

Determination of boundary conditions
- Superstructure parameters
- Substructure parameters
- Train parameters
- Model assumptions

Determine the evaluation criteria
- How do you want to compare the cases?
  - Acceleration
  - Displacement
  - Settlement and more…

Build MBS and FEM model
- Including the different design cases
- Including the different boundary conditions
- Evaluation criteria

Model and simulate the different scenarios
- Do the results seem reasonable?

Evaluate and compare the results according to evaluation criteria for the different scenarios
- Do the results seem reasonable?
- What designs "perform" best?
- Can a new designs be proposed?

Determine how to interpret the evaluation criteria to lifecycle costs
- For example, is their a relationship between the accelerations and displacements and the associated degradation of the track (settlement)?

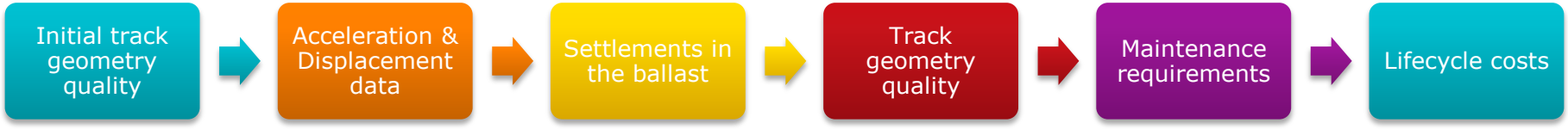
Determine the lifecycle costs that cannot be determined via the MBS/FEM model
- What are the construction costs
- Depreciation costs
- Costs of operational hindrances
- Maintenance costs

Evaluate the lifecycle costs and determine the best solution
- Does the calculated lifecycle costs seem reasonable
- Determine best solution based on the lifecycle cost evaluation

Approach

Difficulties with this approach (1/2)

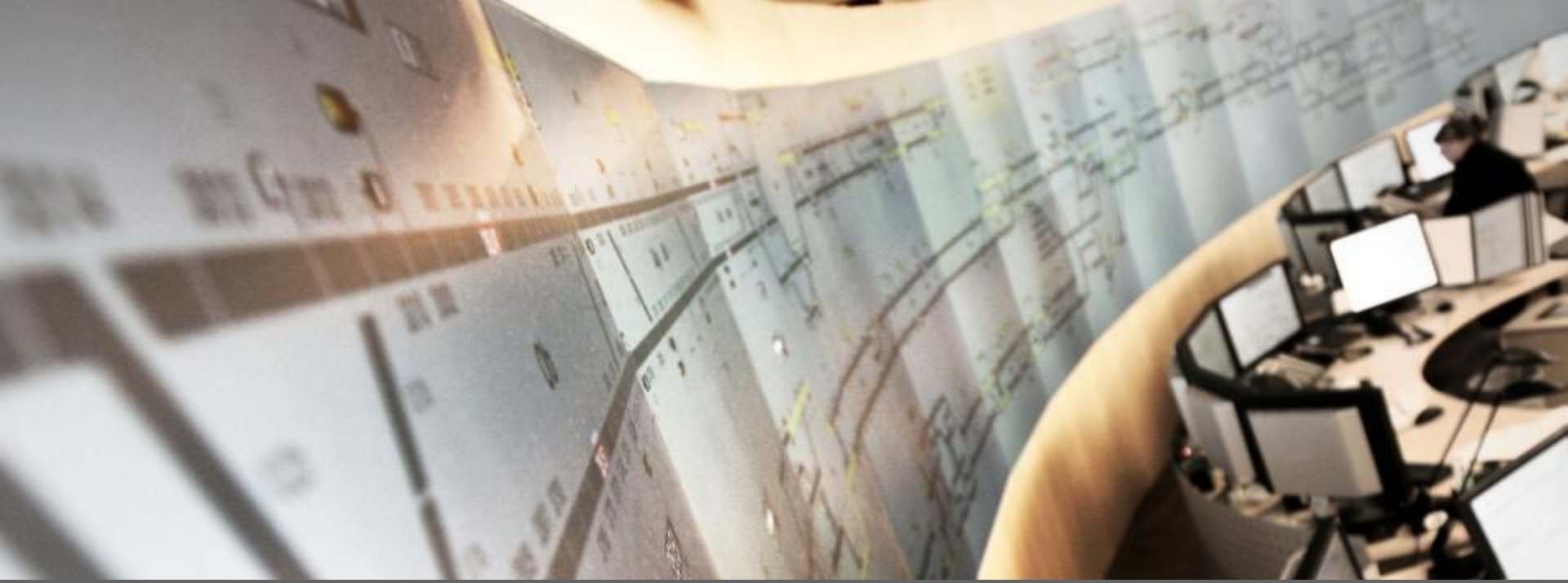
- The simulations and analysis are time consuming
- Simulation of the time dimension is not included
  - MBS/FEM models simulate only one train passage.
    - The models need to consider the number of cycles (i.e. number of train passages)
- It is very difficult to convert the output parameters from the MBS/FEM models to lifecycle costs
  - Such as displacement, stresses, and accelerations to degradation and maintenance costs



Approach

Difficulties with this approach (2/2)

- The substructure conditions have to be modeled.
  - Has a major influence on the calculated results. But it is often difficult to determine the correct assumptions
    - The Elasticity of the substructure layers
      - The performance of the drainage system and the dynamic performance
- The statistical deviations on the input parameters such as rail pad stiffness's, substructure stiffness’s, the vehicle parameters can be difficult to consider.



The ideal decision support tool

Thoughts and ideas…

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Decision support tool

Thoughts and ideas for an integrated model (1/2)

- One model containing an interlinked series of independent models
- Based on some proposed design solutions it shall be possible to
  - Calculate the dynamic parameters
  - Determine the degradation
  - Estimate the lifecycle costs associated with the solution
  - Determine the significance of the input and output parameters

Decision support tool

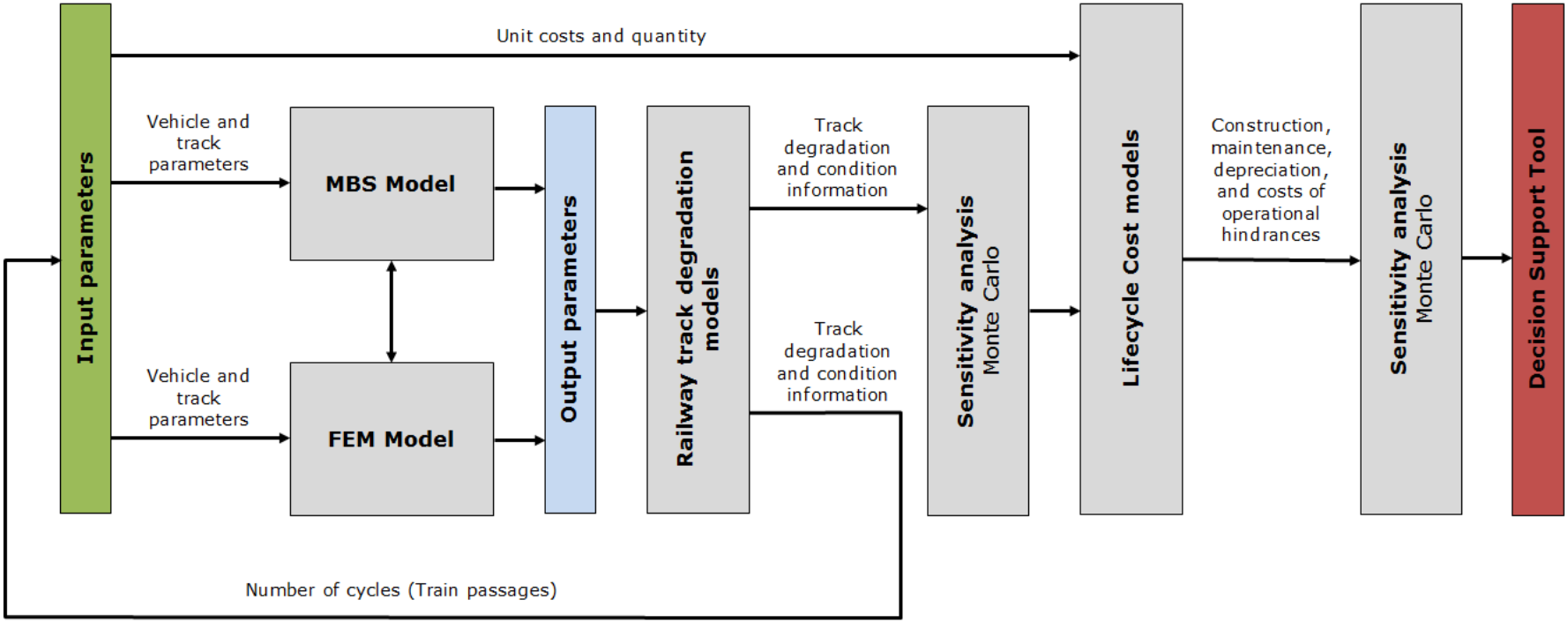
Thoughts and ideas for an integrated model (2/2)

The existing method can be refined and automated, including things such as:

- MBS and FEM models that are linked together
- Statistical analysis tools which evaluate the significance of the model input parameters
- The number of cycles (i.e. train passages) to simulate the time dimension
- Degradation models of the track such as:
  - Track geometry degradation
  - Ballast degradation model
  - Rail and component degradation models
- Lifecycle cost models
  - Which are based on output from the degradation models

Decision support tool

Proposed model set-up



Decision support tool

Challenges and difficulties with this approach (1/2)

- More work needs to be done to link and integrate MBS and FEM models
- Degradation models
  - Degradation models shall be further developed so that they can be linked to MBS and FEM models
    - For example track settlement and track geometry models
  - Degradation models need to take into consideration the effect of maintenance

Decision support tool

Challenges and difficulties with this approach (2/2)

- The link between degradation models and lifecycle cost models shall be improved
  - This will help to determine the maintenance costs
- Construction costs, depreciation costs, and costs of operational hindrances needs to be calculated independently

Conclusions

- MBS/FEM models can help as decision support tools, but they cannot work alone without:
  - Degradation models
  - Lifecycle costs models
  - Sensitivity analysis and statistical considerations
- In the future an integrated model, as proposed could be used as a decision support tool
- More work is needed within the railway sector to make such a model…