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| **WEEK 3: Joining Several Models Together Project Template** |

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Pick an analysis for which your company uses or would like to use modeling from several domains. Then, write a short description of each of the following. Although you will input your replies into the course page, the course team recommends drafting your responses in this document.

**A.** Describe whether, all else being equal, you believe a combined model or separate models makes sense. Even if your company currently has an approach (for example, for weight analysis you use the combined model approach), describe what you believe would make the most sense. (150 words)

I work in the automotive industry where models are crucial to determine many design factors. All over the company there are examples of individual models dedicated to find the necessary design constraints that will meet a given set of requirements. I believe these individual models are great at providing insights on their respective fields. However, they fail to propagate design changes to other areas which makes the design process time consuming and labor intensive. A major task of a vehicle is to provide user comfort and vehicle controllability. In this case, it would make sense to have a combination of models working together. A good example is a model that contains vehicle dynamics, ergonomics, and control systems. With this model, it is possible to evaluate the driver/passenger comfort (motion inside the vehicle) by checking the vehicle responses (dynamics) when a control input from a feature is given to the vehicle. For instance, if the vehicle has an emergency brake system, it is possible to determine the g-forces that a driver will feel when the feature is triggered on a large truck versus a small sedan. Even though these models are difficult to combine, they offer a good solution to determine passenger comfort and provide a competitive product.

**B.** What are some of the challenges in implementing your chosen approach? (100 words)

Connecting these models together is not a trivial task. One of the main challenges is ensuring that all input variables, constraints, and parameters are managed correctly. The control system, for instance, uses vehicle information from the vehicle dynamics model and therefore, the model needs to be setup with the right parameters and physical constraints. At the same time, vehicle reactions are used by the ergonomics model to determine the forces that affect the different types of passengers.

A second challenge of this model is the computational time. The model is required to compute the vehicle equations of motion under dynamic stimuli which can be computationally expensive. Visualization of the simulation of this model also requires a large computational power since it requires to simulate body motion to understand passenger comfort.

The final challenge of this model is the actual validation and verification. Having to validate such model requires an expensive test facility where different vehicle motions need to be controlled and dummy passengers need to be instrumented to measure forces or accelerations.

These challenges are not easy to overcome but once a model is defined, it becomes easier to make up-front decisions on the structure of the vehicle and the software parameters of many different features.

**C.** What do you believe are the advantages of your chosen approach and what are their impact on the organization? (50 words)

There are two advantages of this model. The first one is that it is possible to tune the different control systems relatively quickly without the need to build physical vehicles. This also offers the ability for engineers to understand what portions of the vehicle need to be stiffened or softened to provide a good user experience to the passengers.

The second advantage is that a model of this kind can easily be translated to test multiple features in multiple vehicle configurations. At the end, this model saves the company money and resources by providing a good idea on how the vehicle needs to be designed for comfort based on what features will be available.

**D.** What are the downsides of your chosen approach and the impact on the organization? (50 words)

The main downside of this model is that it requires experts from different disciplines to provide their input. This can be challenging when managing the model or even when using it. This means that the organization needs to have experienced people dedicated to build and maintain the model. Resources need to be dedicated to continuously use data from the field to improve the model and making sure it really works for all vehicle configurations.

**E.** How well do you believe your approach satisfies the qualities of great models that we have built so far? (Refer to Week 3 Takeaways for the 14 Qualities of Great Models; there are four additional ones added this week). Rate the model(s) on high, medium, low achievement of each. (150 words)

1. **Model Fidelity:** High. This type of model haven been in used for a long time and is always being refined with latest features and technology. Equations of motion for vehicles are well known and verification methods have been used to attest for its fidelity.

2. **Model Credibility:** Medium. There are still some differences between modeling and real-life events which makes this model less credible. Engineers are still cautious when make decisions using this model since it affects passenger safety.

3. **Linked to Decision Support:** High. This model provides a good initial set of parameters that helps Engineers align in the design process.

4. **Understandable and Well–Organized.** Medium. Current versions of the model are well documented. However, every new addition to the model requires some expert knowledge to understand and use it.

5. **Well Formed for Optimization:** Medium. Certain areas of the model are more optimized than others. For instance, the solving vehicle motion is more optimized than the crude control system in use. Some of the optimization information is not readily available.

6. **Complete Relative to Scope and Intended Purpose:** Medium. The model is complete in some areas more than in others. For example, not all vehicle communication is available, and not all parameters from the vehicle mechanics is provided.

7. **Clear Scope:** High. The model has a clear scope and is used mainly to determine comfort for passenger in some high technology features or dynamic events.

8. **Internally Consistent:** High. The model is internally consistent. All parameters and variables are in the same units. All constraints are given by physical boundaries.

9. **Elegant:** High. Although sometimes difficult to use, this model has been refined to use economy as much as possible.

10. **Analyzable and Traceable:** High. The model is analyzable and traceable. It not only explains the output of the system, but it is possible to visualize some of the transient responses if necessary. It is also possible to make sensitivity analysis on certain parameters using this model which makes it very useful for improving the design.

11. **Avoid Optimizing on a Black Box:** High. Nothing within the model is treated as black box. Everything is well connected and coupled as required.

12. **Data Extrapolation:** High. The model clearly describes the areas where it is valid and not valid based on the input parameters. There is also a possibility to understand the effect of certain ranges of input parameters if they are not fully defined.

13. **Availability of Interfaces:** High. The data and outputs are always accessible for the user to validate the model at transient responses.

14. **Reusable:** High. The model is very reusable. This model can be used on different vehicle configurations, for different control system features, and for different types of passengers at different positions in the vehicle.