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Preface

Notations

Example:

**Roman upper case letters**

 Variable notation for something

 Variable notation for something

 Variable notation for something

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 Variable notation for something

 Variable notation for something

 Variable notation for something

**etc**

# Introduction

## Objective

Need for longer combination trucks- briefly into advantages- stress on limitations of the initiative- concerns about meeting performance demands- introduce the idea of hybridization of the trucks-the potential benefits through added propulsion but how added costs may deter customers- Thus establishing a need to develop a tool to provide a way to arrive at the most productive solution if hybridization was to be considered.

## Statement

Just the project statement.

## Scope

Here mainly a look into what the report will cover and what it will not- How the tool will be used primarily to study trends helping us identify the components that most affect the productivity-thus the model of the truck was not intended for complexity

## Outline

Provide a layout or overview of the project report by outlining the sections: productivity, vehicle model and optimization tool.

# Literature Review

## Hybrid Powertrains

### Topology

#### Parallel

#### Series

#### Plug-In

### Feasibility

Talk about the existing projects of hybrids on heavy trucks

## Energy Management Strategy

### Heuristic Control

### ECMS

### Predictive Control

### Optimal Control

## Productivity

## Optimization

# Vehicle Model

## Driving Cycle

The aim of the project is to find the most productive vehicle combination for a particular route. The route chosen for this is the E20/E6 highway from Gӧteborg to Malmӧ. This particular journey back and forth is quite popular among companies transporting goods and any findings of the report will be of key interest.

The driving cycle data provided includes x,y and z axis coordinate readings from an on-board GPS. Along with these are readings of instantaneous speed, recorded with a frequency of 1Hz. On subsequent study the speed signal was found to have too much noise making it unusable. The position signals have some issues that posed problems at first. The data is used to obtain the values of the slope of the road along the z axis since the vehicle model is represented as a one-track bicycle model and lateral effects are neglected. This is done as

The resolution of the position data was determined to be too low which caused problems when the slope was calculated as there were sudden big jumps in the slope values. This was circumvented by introducing a splinefit for the position data along each axis. This ensured that the data is less step like. The slope was then recalculated using equation (?). As the position values are logged at each second the slope tended to change with the same frequency hence resulting in a very noisy signal defined against time. To provide a smoother signal a rolling average filter was used. This approximates the slope over a range of old data to the average slope in that range. The size of the range is dependent on the speed of the truck (i.e. taking a small sample size when the truck is moving faster and vice-versa) in order to provide a more realistic slope signal. Lastly the slope signal was redefined as against distance rather than time.

The slope data is sent to a driver model which in-turn provides values of the tractive force demanded of the truck at each instant. This is explained in more detail in Section 3.3.

## Driver Model

The slope data is defined as against distance as the vehicles current position is calculated at each instant and the slope for that position is interpolated using the data. The slope information along with the vehicle parameters are used to calculate the total road resistive force as according to the equations

The inertial effects of rotation were taken into account through the equations ()

The driver is designed to be aggressive with the acceleration as the aim is to get the truck to maintain a top speed (80 kmph) whenever traction is available. Based on this logic a subsequent desired acceleration force is calculated which is indicative of the amount of force needed to propel the truck to the max speed in the next instant. This term also ensures that the trucks does not speed over the 80kmph limit which could be likely during downhill conditions as the acceleration force in this case would be negative. The total demanded torque is given as

This demand is sent to the vehicle model which returns the achieved acceleration for each time step.

## Vehicle Model Structure and Function

The vehicle model was constructed to be represented as a combination of a number of sub structures, each of which encapsulated certain functionality and properties. This was done to maintain the real world relation between the various components. Traction requests that are demanded from the trucks flow down the structure till they are represented as individual requests from the machines. It also allows for future work on the model to modify components separately. The substructure below follows as:

Units

Axles

Transmission

Machines

Buffers

The truck is constructed using the genetic chromosome as a blueprint as mentioned in Section 2.4. The units, axles, buffers and axles associated to these units, and the subsequent machines and transmissions associated to these axles and buffers are constructed setting up structure of the combination. This is followed by a startability check which allows for dismissal of unsuitable combinations earlier thus saving on processing time.

The combination level which dictates the overall layout of the truck encapsulates the functionality for the driver model, energy management strategy (EMS), startability check and vehicle productivity calculation. Once the overall traction demand for an instant is calculated this is checked against the maximum grip limit traction capability and if found to be greater, the value for traction request is limited to the latter.

The traction is then distributed between the units which is handled by the EMS the explanation for which is covered in Section 3.4. Once the traction trickles down the structure and is assigned as torque request at the machine level the overall traction that can be produced is recalculated bottom-up from the machines to the combination. This provides information on the instantaneous acceleration provided as in equations

This through the basic motion equations is used to determine the distance travelled and speed at the next instant taking a cycle frequency of 1Hz. This continues till the total distance is covered.

### Units

The overall truck combination are represented as a collection of 4 units- the tractor, first semi-trailer, dolly and the second semitrailer. The properties that are associated to the units and which vary between them are the overall units load, the battery or fuel tank associated to the units, total number of axles and the number of driven axles.

When a traction request is provided to the unit it is checked against the maximum propulsive or regenerative capacity of the units as a whole. In order to determine this value which is a machine property varying with machine speed, the axle speed is set which in-turn passes through the axle differential and machine gearbox and translates to the machine speed. Thus cumulative maximum positive or negative tractive capacity is then determined. If the traction request is found to be less than this value and if the buffer associated to the unit is within operable range (explained in greater detail in Section 3.4) then the traction request is divided equally between driven axles.

### Axles

The individual axle loads are defined for each axle which provides information on the tractive capabilities of that axle through a check for grip limitation. Each axle is either non-driven or is linked to a transmission and machine which may either be a motor or an engine in the case of the tractor unit axles. The axle has the final drive ratio associated with it. It is used to gear down the wheel speeds to a gearbox shaft speed as according to equation (?)

So when a traction demand passes down to an axle, clears the grip limitation check and passes past the axle differential, it is sent to the machine transmissions.

### Transmission

The transmission linked to the axles possess the same structure regardless of the machine. The only property that varies is in fact the number of gears. The functionality associated at this level is simply to encapsulate the gear losses and reduction effects so as to arrive at the machine torque and speed given the selection gear as can be seen in equations (?)

When the axle speed information is passed down to the transmission the gear is selected as described in Section 3.2, the machine speed is calculated as above and is used by the machine.

### Machines

At the machine level the machine speed is set as per information derived from the transmission. Once the machine speed is set the maximum propulsive torque and in the case of a motor, the maximum regenerative torque are identified for the current speed. This information is accessed at the unit level as mentioned in Section 3.2.1.

The torque requests are checked against the maximum torque capabilities regardless of whether it is positive propulsion torque or in the case of an electric motor, negative regenerative torque. If it within acceptable limits the machine torque is set to the demand value. The machine power to be demanded from the associated buffer is then calculated as

### Buffer

The buffers associated to the machines are a fuel tank in the case of an engine and a battery when the machine is an electric motor. They are provided with information of the power demand along with the electric machine efficiency or the brake specific fuel consumption of the engine for that operation point of that machine respectively. The energy demand for that particular instant is calculated by assuming that the power is constant for a fixed time interval that the whole cycle has been discretised into (1 second by default).

#### Fuel Tank

On receiving the power demand, the amount of fuel to be consumed from the fuel tank to provide the power is calculated for that instant as shown below

The overall fuel level is then reduced by this instantaneous value.

#### Battery

The properties associated with the battery are the current state of charge (SoC) , the total battery capacity and open circuit voltage. The SoC of the battery plays a vital role in determining the torque request to the associated motors as it is essential that the SoC is kept within safe limits of operation. This will be explained in more detail in Section 3.4.

When power is demanded from the battery information of the operating efficiency of the machine is also sent. This helps calculate the total charge demanded at each instant.

This demand whether positive or negative will in turn append the overall SoC as shown

## Energy Management Strategy

Ref. of road load and predicted acceleration then give a representation of the general rules in fig. followed by an explanation the choices made.

Information about predictive depth of discharge would also be provided in this section

# Validation

## Variants

### Truck Variants

Different axle loading, GCW

### Engine Variants

Both this and the ones below contain specs of individual in a tabular format followed by explanation of the choices made

### Motor Variants

### Battery Variants

This part will incl. the calculation of what charge capability was reqd and how the battery choices were arrived at from there.

## Model Validation Results

**<The existing results report shown earlier will be inserted within this section>**

# Results and Discussion

Start with optimization parameters chosen

## Productivity Trends

Productivity trends recorded for changes over time w.r.t. fuel prices, driver wages, battery prices etc.

# Conclusion

# Scope of Future Work

This section will capture the limitations of the existing study and propose new directions to investigate

# References

Familyname1, X., Familyname2, Y. (YEAR): Name of paper. *Name of Journal*, Vol. xx, No. yy, {month} year, pp. xx-yy.

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# Appendix