Logistics of Earthmoving Operations
Simulation and Optimization

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Introduction

- a 3-year project (2011-2013) financed by Vinnova
- Collaboration between Volvo Construction Equipment (Volvo CE) and KTH
- Volvo CE is one business area of Volvo Group, and develops and manufactures equipment for the construction industry. Example of construction machinery:
  - wheel loader
  - excavator
  - articulated hauler
  - motor grader
  - etc.
Optimized Transport Solutions
Objectives

- Develop a simulation-based optimization framework to act as a sales tool to help the customers optimizing their fleet and eventually their sites
  - Create a simulation system of earthmoving logistics
  - Formulate and solve optimization problems for earthmoving operations
Simulation of Earthmoving Operations
Aim

- Design a microscopic discrete event simulation system for modeling earthmoving operations and conducting productivity estimations in terms of Total Cost of Ownership (TCO) and environmental aspects
  - A TCO analysis includes
    - total cost of acquisition
    - the operating cost
    - the productivity of a project
  - Discrete event simulation techniques are used to capture the interactions between the resources and the randomness of each of the activities
  - The microscopic model represents site operation and individual equipment at a very detailed level
The Framework of Microscopic Simulation Model

**User Input**
- Site & fleet configuration
  - Haulage road’s characteristics
  - Earth Characteristic
  - Equipment fleet

- Project information
  - Scope of work
  - Work schedule
  - Capital & operating costs

**Microscopic Simulation Model**

**Simulation of equipment dynamic performance**

**Outputs from dynamic simulation**
- Activities’ duration
- Activities’ fuel consumption

**Discrete-event simulation of earthmoving logistics**

**Productivity report**
The Output of the Discrete Event Simulation

- productivity: transported material per operating hour [ton/h]
- TCO: cost (capital & operating cost) per production unit [SEK/ton]
- queue statistics of resources
  - loading unit’s idle time due to unavailability of hauling unit, and coffee and lunch breaks
  - hauling unit’s idle time due to unavailability of loading unit, crusher capacity limit, and coffee and lunch breaks
Simulation-based Optimization of Earthmoving Operations
Aim

- Create a simulation-based optimization framework to act as a sales tool to help the customers optimize their fleet.
Optimization Problem Formulation

\[
\begin{align*}
\min & \quad \text{TCO} \\
\text{s. t.} & \quad P \geq P_{\min} \\
& \quad \sum_{l=1}^{L} \sum_{b=1}^{B_l} x_{l,b} \leq N_{\text{LU}}^{\max} \\
& \quad \sum_{h=1}^{H} y_{h} \leq N_{\text{HU}}^{\max} \\
& \quad x_{l,b} \in \{0,1,2,\ldots,N_{\text{LU}}^{\max}\} \\
& \quad y_{h} \in \{0,1,2,\ldots,N_{\text{HU}}^{\max}\}
\end{align*}
\]

\( P \): the production rate (tonne/h)
\( P_{\min} \): the given minimum production rate
\( N_{\text{LU}}^{\max} \): the maximum number of loading units
\( N_{\text{HU}}^{\max} \): the maximum number of hauling units
\( x_{l,b} \): the integer variable representing the number of loading unit of model \( l \) with bucket size \( b \)
\( y_{h} \): the integer variable refers to the number of hauling unit model \( h \)
New project (2014-2016)

New application approved by VINNOVA: Lean Earthmoving in Dynamic Environments (2014-2016)

- focus on the lifetime of earthworks
- construction projects are highly dynamic and the working environment at the construction sites is re-configured constantly
Thank You and Questions?