Why engineering simulation models configurability and flexibility matter

Webinar on 2022-10-26 by:

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FlexSim problem solved.®

Agenda

- What is operations simulation?
- Why is it important to engineering?
- What makes it even better: configurability!
- A flexible and limitless platform
- Example 1: scheduling for a food processing plant
- Example 2: material handling and traffic debottlenecking
- Final words

What is operations simulation?

Why using a model?

Asset condition monitoring and increase of uptime

Methodic de-bottlenecking and economic ramp-up

Develop smart solutions for mines, plants, buildings, cities, …

Locate, track and quantify wait times & unproductive delays

Diagnose and optimize process controls

Forecast demand and anticipate productivity

Improve scheduling & supply chain efficiency

Democratic information sharing between people & systems

Real throughput?
Best schedule?
Enough resources?
Deliver on time?
Reduce costs?
Scale up?

Typical model elements

≡ Operations simulation models capture all aspects of a production system to help analyzing and improving the global operational performance:

- **Schedules** daily shifts, weekly production, planned maintenance
- **Equipment** capacities, reliability, buffers, storage, conveying, piping
- **Operators** activities duration, task coordination, procedures
- **Maintenance** spare parts, work orders, repair times
- **Transport** mode, traffic, speed, loading times, queuing at intersect.

About event-based modelling

Model systems which change states at discrete points in time as a result of specific events

Examples of EVENTS

- Order/part arrivals
- Product movement
- Machine process start/finish
- Machine breakdown/repair

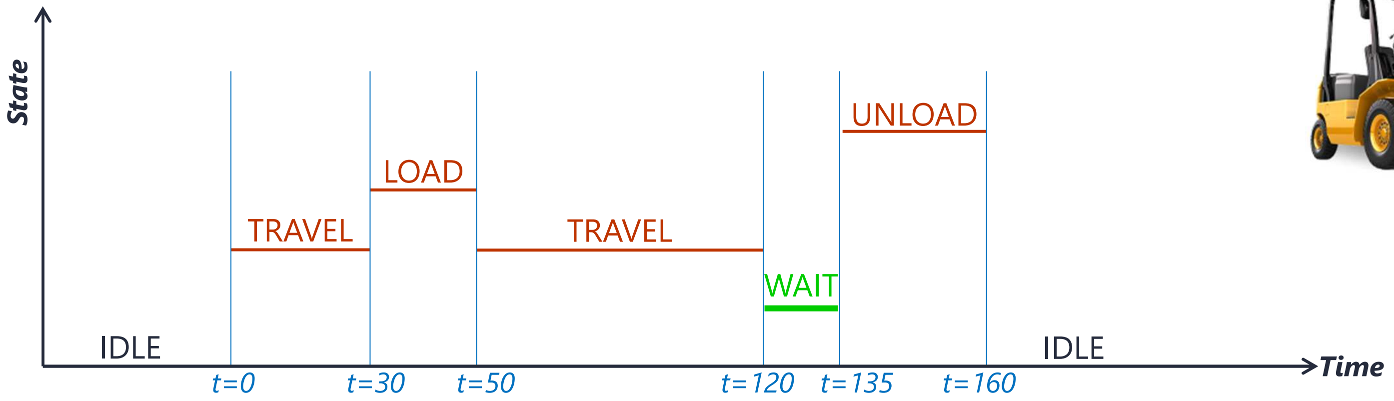
Examples of STATES

- Machines: idle, setup, processing, down
- Queues: empty, full
- Operators: on-shift, off-shift, utilized, idle
- Transports: travelling, loading, unloading

Simulation QUEUE and CLOCK

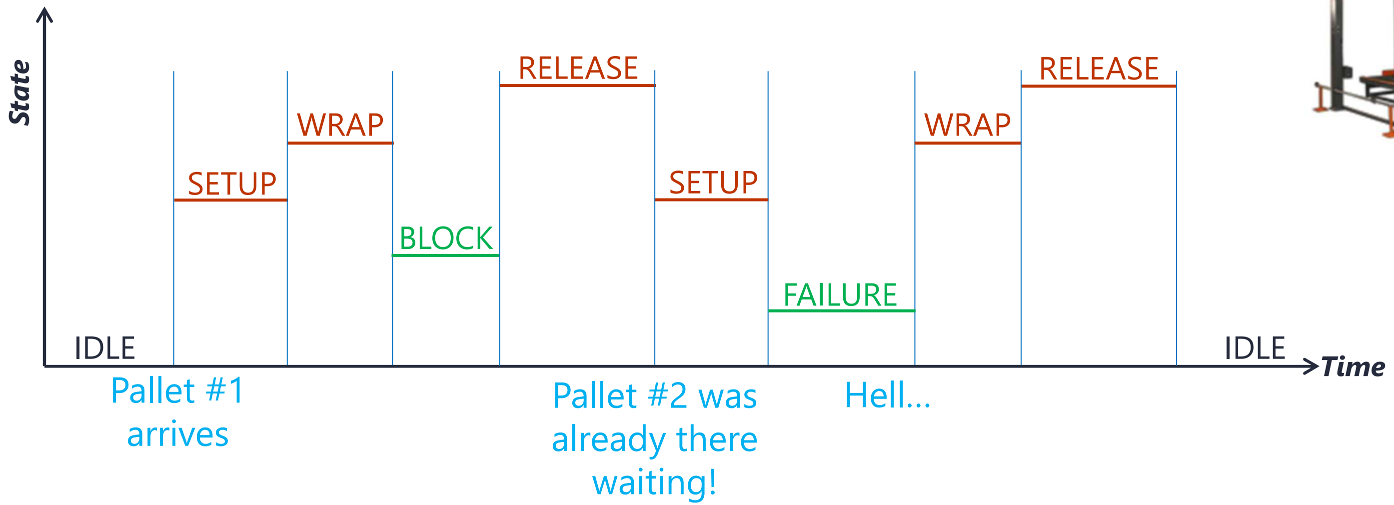
- Event execution & state updating trigger future events
- All events are put in a time-sorted queue
- The simulator jumps to the next timed event and executes it

Example: moving a box



Box to be moved! → Call a forklift → Drop zone is overcrowded → Box delivered + Forklift freed

Example: pallet stretch wrapper



Event-based modelling

The mental exercise behind event-based modelling is:

Understand WHAT can cause changes in states

Figure out HOW system elements react to changes in states

This explains WHY and WHEN events are triggered

We obtain a model that describes **how elements behave** and **interact together** in the system

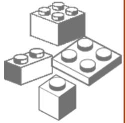
Even without a computer implementation, investigating and developing this vision of a system is value added!

Building blocks of complex systems

Most production systems and supply chains can be decomposed, modelled and optimized using these elements!

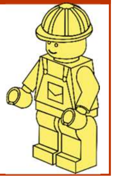
Variability

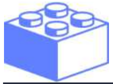
- Probability distributions
- Delays and rates
- Uncertainty tolerances



Management

- Scheduler
- Dispatcher/regulator
- Assets tracking
- Performance monitoring





Delay

- Cycle time
- Time to failure
- Repair time

Rate

- Vehicle speed
- Bulk/liquid flow
- Items arrival

Wait

- Queue (FIFO)
- Stack (LIFO)
- Priority pick

Inventory

- Items storage
- Parts buffer
- Tank/silo

Why is it important for engineering?

Engineering design challenges

Obtaining the perfect system design that will operate smoothly and efficiently is not straightforward…

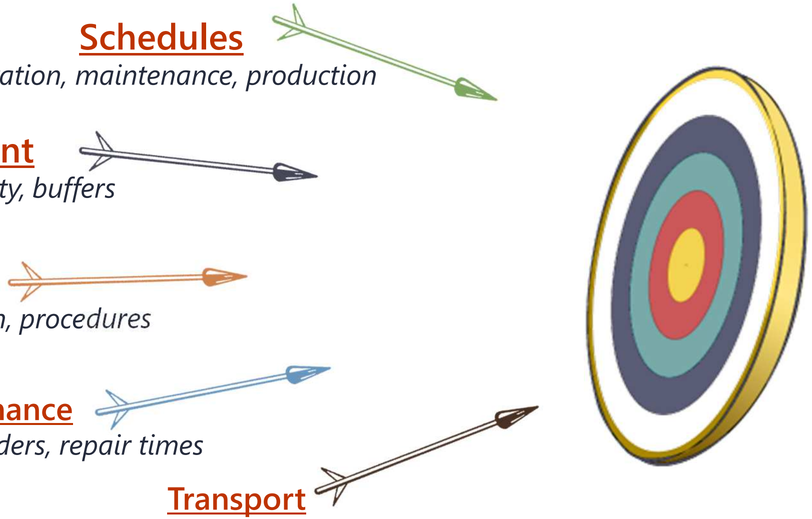
Schedules
operation, maintenance, production

Equipment
capacities, reliability, buffers

Operators
cycle times, task coordination, procedures

Maintenance
spare parts, work orders, repair times

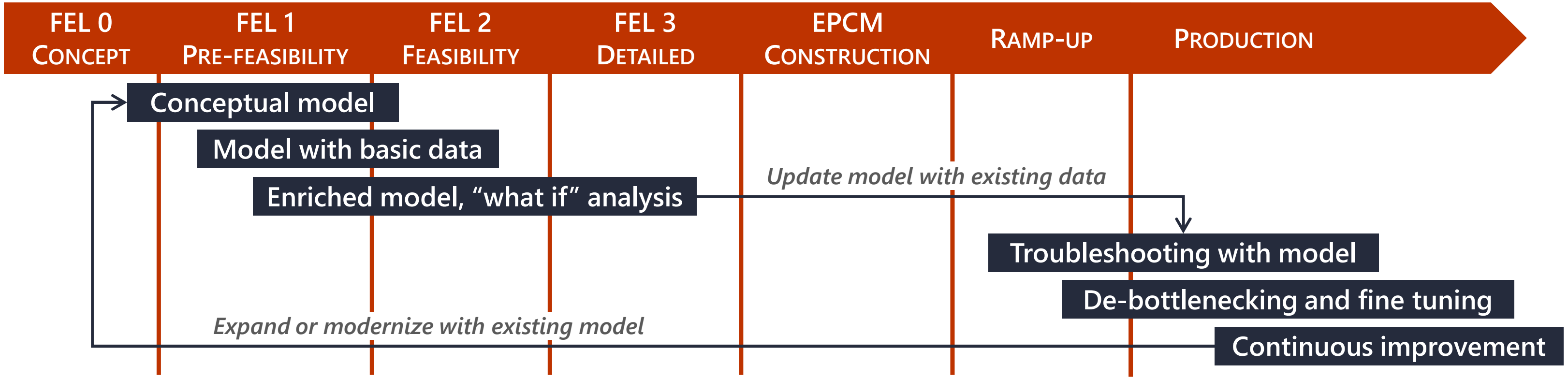
Transport
fleets, traffic, modes



How to make sure that operations performance is a perfect hit at the design stage?

Typical engineering design cycles

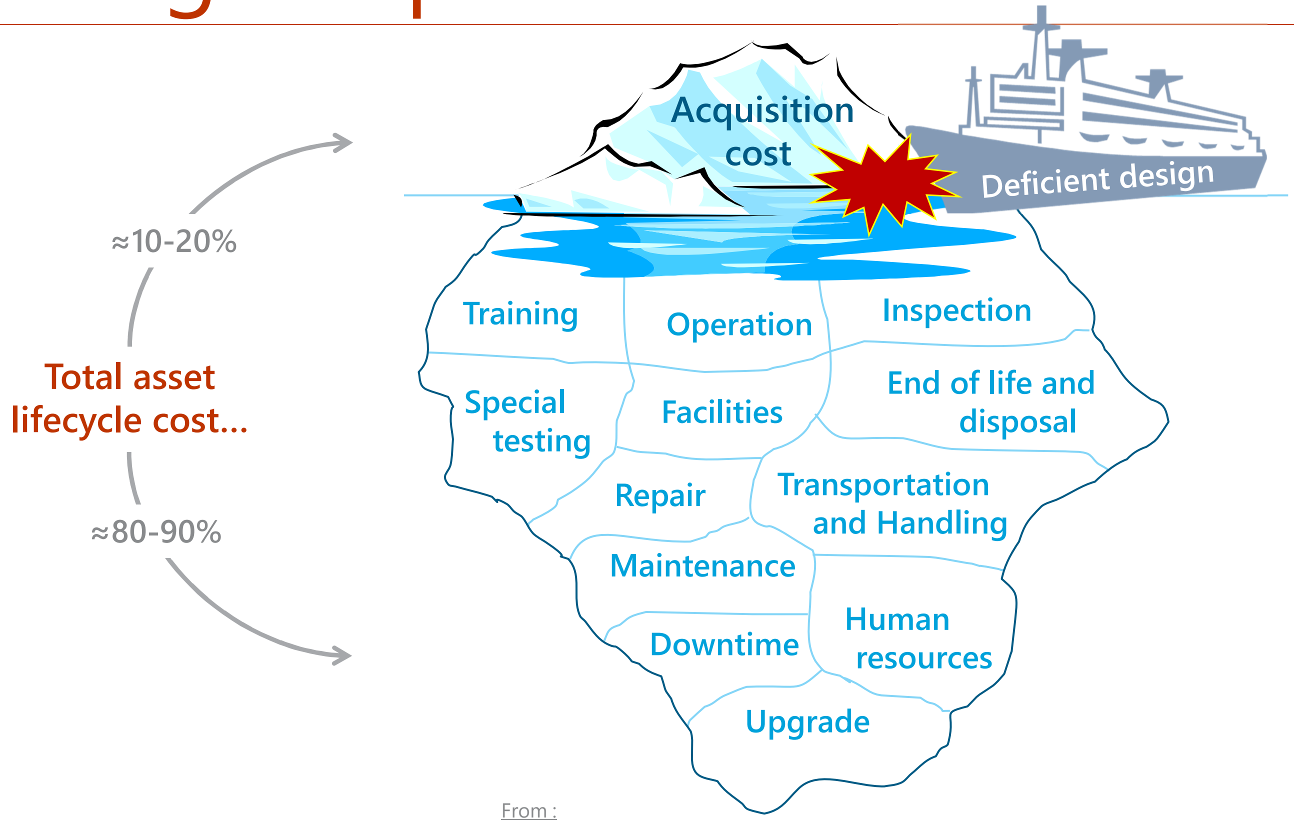
Simulation should be used from early stages to increase the chances of a perfect target hit on operational performance!



- ✓ Evaluation of operations feasibility
- ✓ Elimination of over-design
- ✓ Sizing of fleets and equipment capacities
- ✓ Analysis of alternative designs
- ✓ Evaluation of equipment maintainability

- ✓ Debottlenecking of operations
- ✓ Assessment of real production capacity
- ✓ Optimization of schedules and equipment
- ✓ Analysis of improvement scenarios
- ✓ Support to Lean Six Sigma projects

Design impacts the total cost…



From :
An Introduction to Life Cycle Engineering & Costing for Innovative Infrastructure (ISIS Canada)
http://documents.mx/documents/an-introduction-to-life-cycle-engineering-costing-for-innovative-infrastructure-isis-educational-module-7-produced-by-isis-canada.html

Operational thinking during design

Operations simulation brings an operational thinking at the design stages to ensure the whole life usefulness

The process

Inputs? Outputs?
Value added steps?

Equipment

Quantities? Configuration?
Capacities? Reliability?

Layouts

Effective flows? Storage
vs working areas?

TYPICAL ENGINEERING FOCUS

Maintenance

Cleaning?
Inspection?
Lubrication?

Interventions

Ease of repairing?
Replacements?
Parts and tools?

Everything is interrelated!

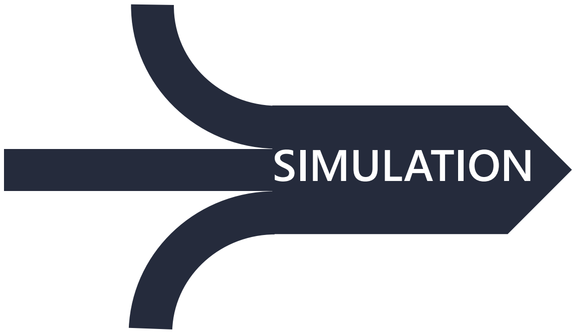
Are equipment and layouts optimized for operations and maintenance?

The perfect design testing sandbox!

Layouts, routes, dimensions, stationary and mobile equipment characteristics, technical data

DESIGN SPECIFICATIONS
engineering

HISTORICAL PROCESS DATA
data science



OPERATIONS KNOWLEDGE
people

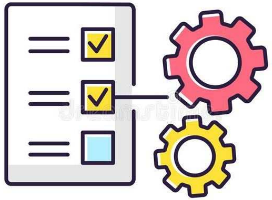
Cycle times, schedules, resources availability, logic, routing and operational constraints, reliability

Outputs:

≡ Performance diagnosis
≡ Effective and ultimate throughput
≡ Equipment utilization rates
≡ Meaningful and custom statistics
≡ Trend and pie charts, histograms

Trials and errors for “free”!
No consequences!

What makes it even better: configurability!



Different modelling flavours

Design sandbox

- ✓ Best estimator of expected assets
- ✓ System parameters TBD
- ✓ Resource counts TBD
- ✓ Layout and visuals TBD
- ✓ Purpose: determine the ideal system parameters (the design!)

Digital twin

- ✓ Virtual duplicate of existing assets
- ✓ Fine details on system parameters
- ✓ Calibrated with recent data
- ✓ Hi-Fi interactive 3D visuals (immersive VR if possible)
- ✓ Purpose: understand the deviance from the designed base conditions

Different modelling flavours

- Brings back to the fundamental question when starting a modelling task: what are the questions to be answered?

  - Looking for a “designed base conditions keeper”?
  - Need a Digital Twin!

  - Looking for the system design itself?
  - Looking for an engineering design sandbox!

Designing a configurable sandbox

≡ Shifting the mindset is crucial!

Create a model, implement it and generate outputs

Traditional model development approach and usage by the model developer

Deliver a scientific app implemented in a simulation platform

Software-oriented mindset with planned user interaction (inputs) and feedback (decision-ready outputs)

Model configurability in practice

≡ The secrets:

- Adopt an object-oriented modelling mindset
  - Break down the system in objects that will interact together
  - Objects population are easy to parameter: fleet sizes, number of processing lines, number of operators, etc.
  - Highlight which parameters are required by the objects to make decisions and to be configured

- Adopt a database mindset for the inputs
  - Before editing the model, think to all required parameters
  - Easy when an object-oriented model design exists…
  - Prepare a database schema of the inputs!

Model configurability in practice

- Spend more efforts upfront:
  - Before coding, prepare 3 diagrams:
    - The model scope: major activities, logical steps and streams, inputs to the model (the triggers), outputs (the end points)
    - The objects: the components of the model, their main roles-duties-features, their relationships
    - The input data: a database schema
  - Store and manage the inputs with rigor
    - Garbage in, garbage out…
    - In Excel spreadsheets with data validation and dropdowns
    - In a database for stronger type checking and data indexing
  - Prepare yourself to spend time managing the inputs
    - There will be scripts to write to parse the information
    - There will be scripts to write to construct the model on-the-fly

Illustration: (1) model scope

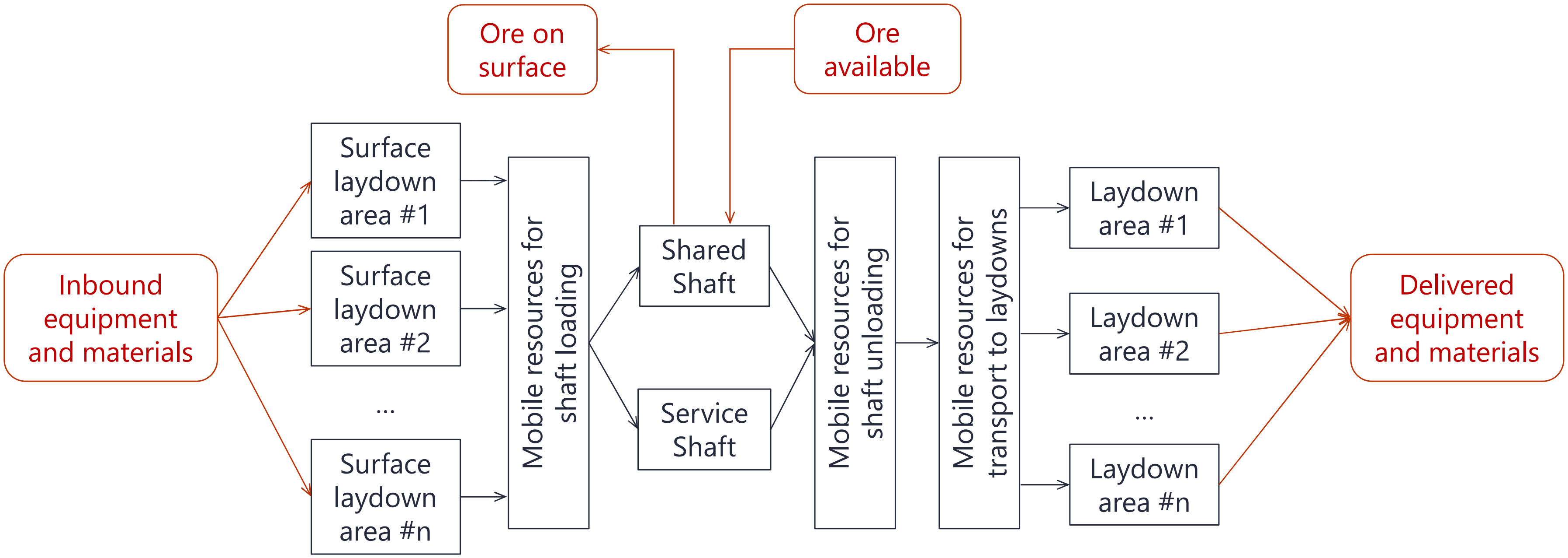


Illustration: (2) model components

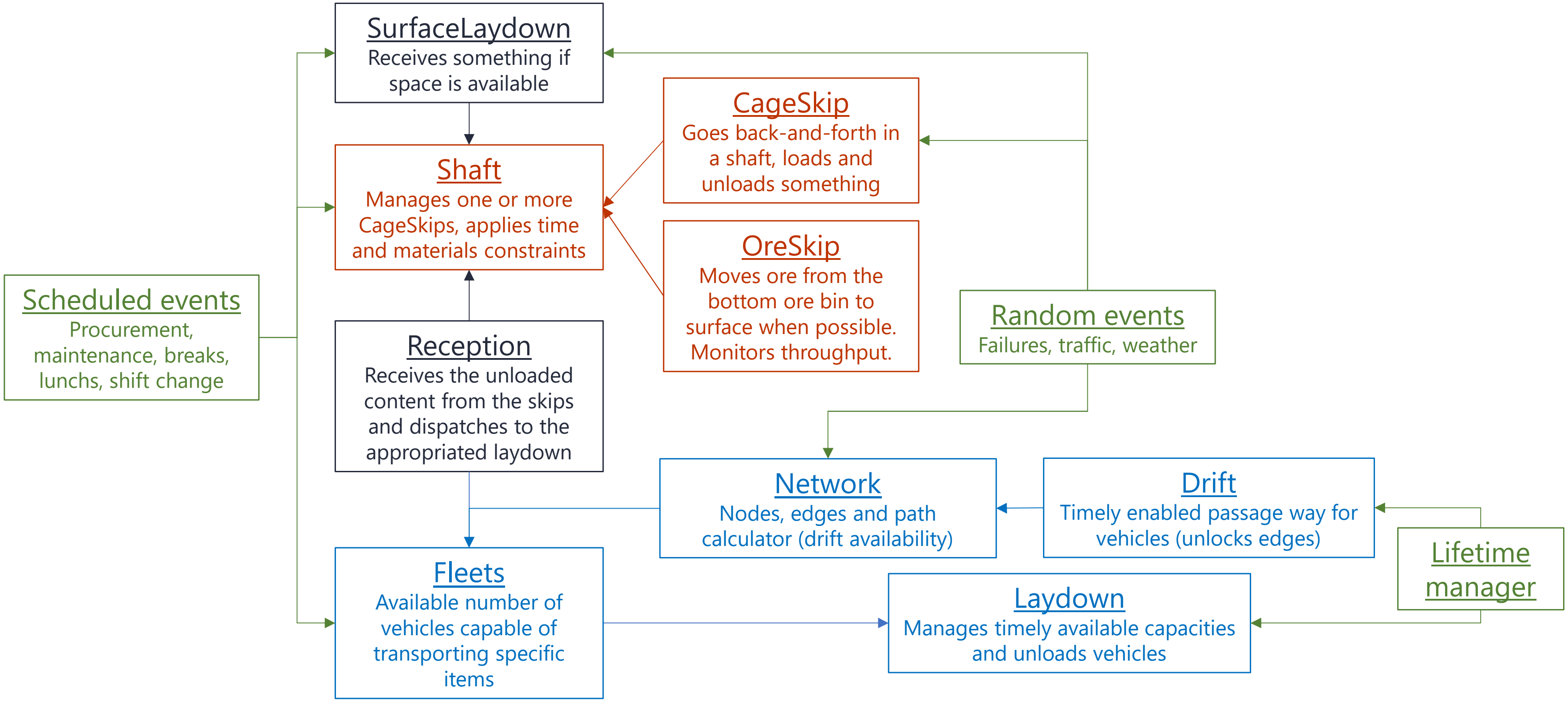
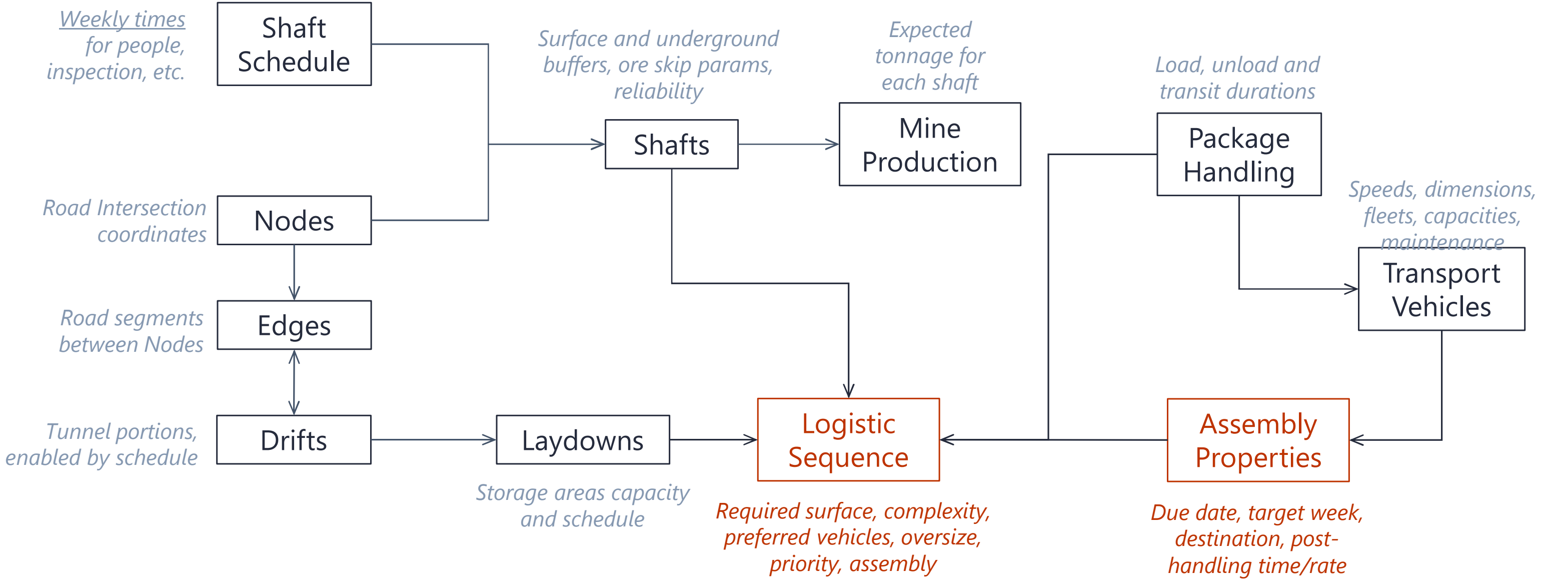


Illustration: (3) inputs diagram



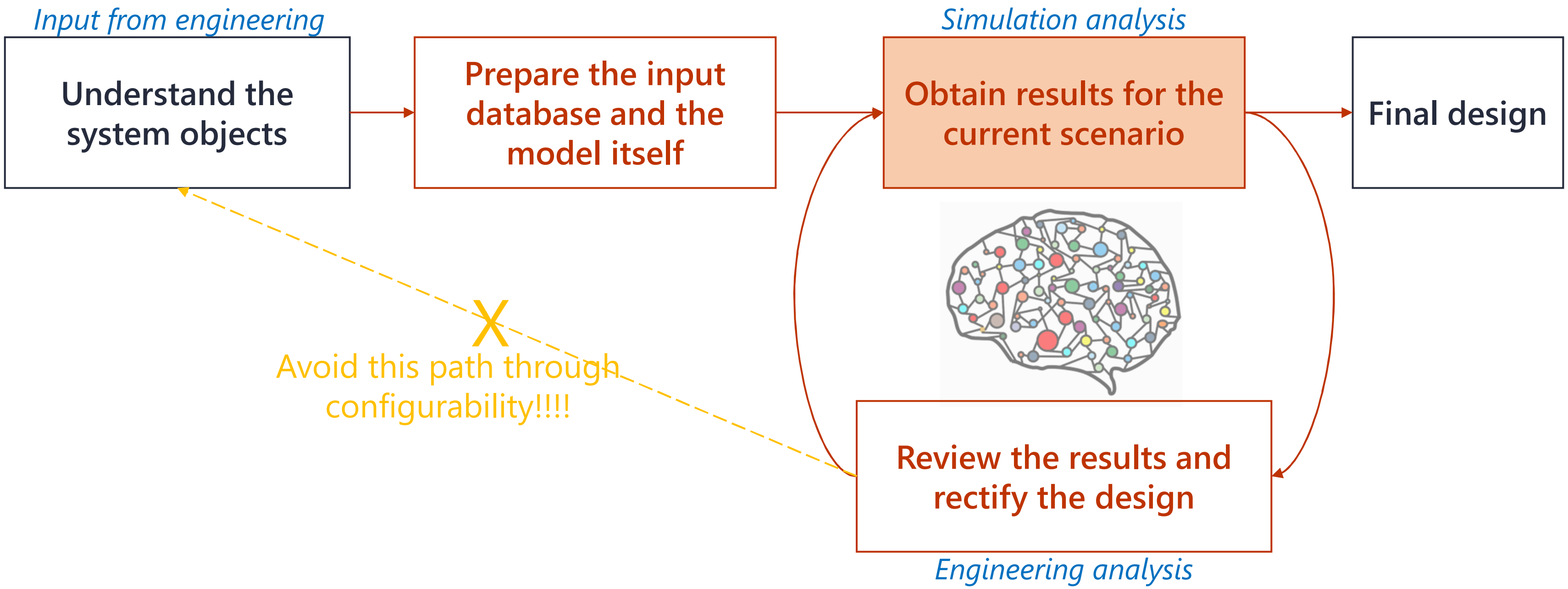
Upfront efforts always pay!

≡ Some benefits of this approach:

- Standardized model development process
  - Opens to concurrent model editing!
  - Opens to quality management
  - **One model source file for all scenarios!**
- When iterating, adding model features is much easier
  - Not “will”, but “when & what” will engineers think of down the road?
  - Adding objects and input tables is simpler with the diagrams
- Documenting trials is “built in”
  - One file or DB instance per scenario
  - “Uhhh… What did we try???” easy to answer!
- Overall less effort during the whole engineering cycle

Iterative simulation-assisted designing

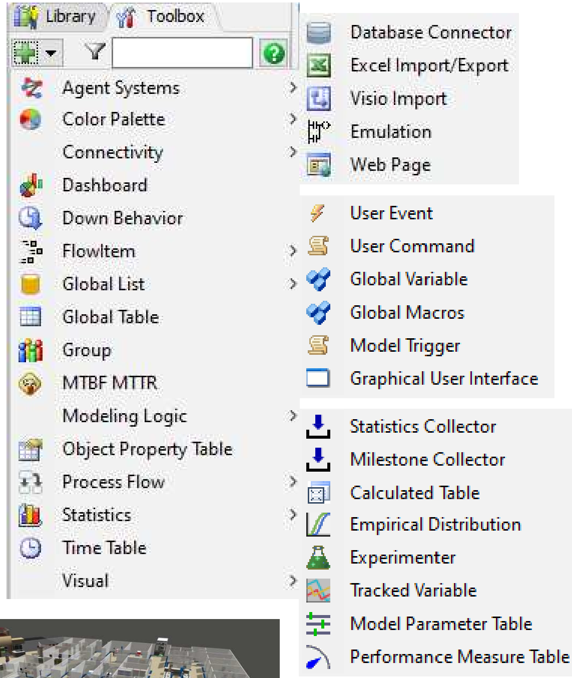
≡ Engineering iterations are much faster and easier

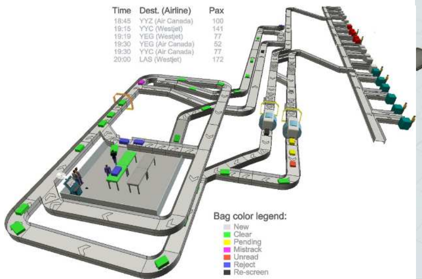


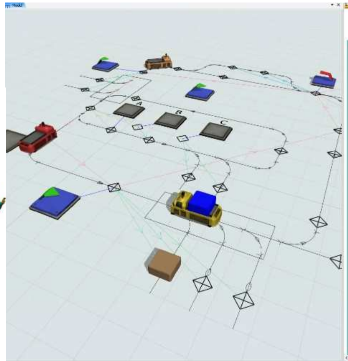
A flexible and limitless platform

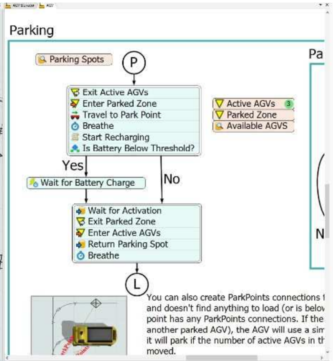
A flexible and limitless platform

- Powerful 3D interactive object-oriented environment
- Several built-in object libraries usable off-the-shelf
- Open architecture and user modules: develop and reuse your own libraries
- Interoperability with known technologies : Excel, local/remote SQL databases, CAD drawings, PLC, etc.
- Comprehensive toolbox to quickly develop models









Example 1: scheduling for a food processing plant

On the complexity of dairy plants

- Why is scheduling so complicated?
  - High number of possible production lots permutations
  - Different and variable lot/batch sizes must be used
  - Product incompatibilities need to be managed
  - Allocation and priority to use share resources (CIP…)
- What is it all about?
  - Eliminate undesired waiting times
  - Shorten run lengths and avoid over-time
  - Manage limited holding tanks/silos properly

Evolving the plant…

≡ The weekly "ordinary" challenges

- Accommodate additional volumes: how will we do it?
- Re-scheduling during the week because…?
- Eliminate overtime and deliver on time

≡ Plant expansions

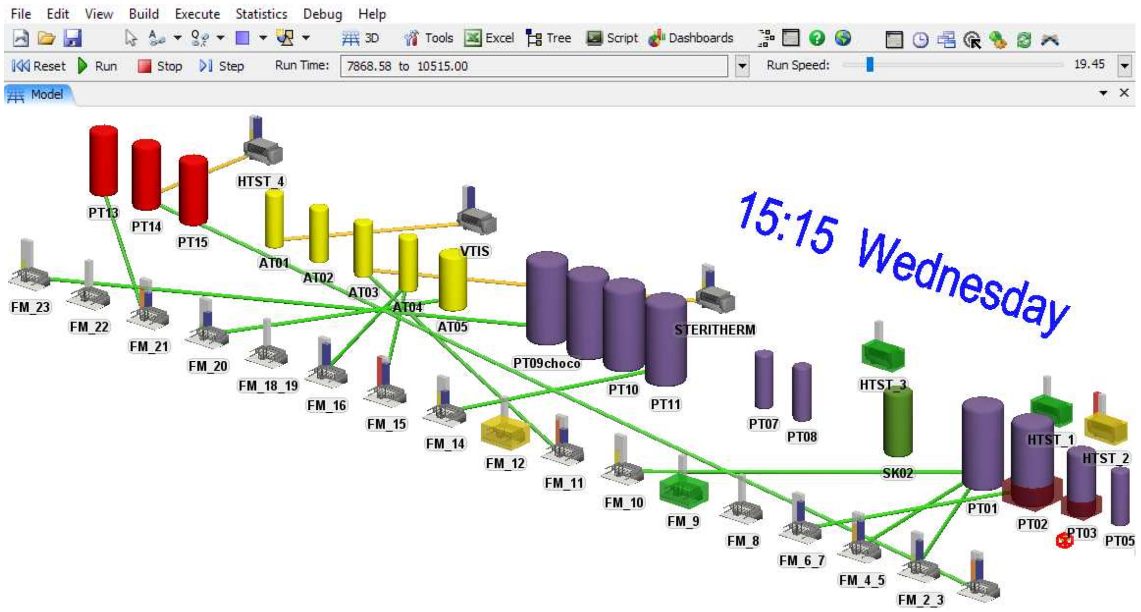
- How many additional silos, which capacity?
- How many new fillers, required flowrates?
- What is the effective new capacity?

≡ Network-wide optimization

- Redistribute the total load across several plants?
- Minimize trucking to client warehouses?

Visit of the model...

- The input...
- The model...
- The outputs...



Using the model

Improving an historically hand-made refined schedule:

Day:	1	2	3	4	5	6	7	GLOBAL
R1		100	100	100	50	50		90
R2	100	100	100	80	80	80		96
R3		100	100	67	67	67		91
R4		100	100	100	80	100		100
R5		100	100	100	80	100		100
R6		100		80	43	86		96
R8		100	100	100	50	100		100
R9		100						100
R20	83	100	100	100	75	100		100
R21		100	100	100	100	100		100
R23								
R24		100	100	100	100			100

	Before	After	Gain
Total lost time (h)	254	60	-76%
Total available time (h)	890	1,021	+15%
Orders fulfilment	94.8%	100%	

After 1 hour of simulation work

Day:	1	2	3	4	5	6	7	GLOBAL
R1		100	100	100	100	100		100
R2	100	100	100	100	100	100		100
R3		100	100	100	100	100		100
R4		100	100	100	100	100		100
R5		100	100	100	100	100		100
R6		100		100	100	100		100
R8		100	100	100	100	100		100
R9		100		100	100	100		100
R20	83	100	100	100	100	100		100
R21		100	100	100	100	100		100
R23								
R24		100	100	100	100			100

Using the model

- Initial purpose: plant expansion
  - This model was developed to support and engineering project
  - The project mission was to increase by 75% the plant capacity
  - The model helped sizing the new silos and deciding which new fillers and pasteurizer upgrades were the best options
    - Optimal schedules were developed at each stage of the design
- Then, the client asked to get the model for its own use
  - Wanted to leverage this new value adding tool
  - With limited training, the client reconfigured the input file to model several other plants… without the modeler!
  - No need to modify the simulator's code, only Excel work…

Example 2: material handling and traffic debottlenecking

Material handling in a mine

≡ Why is it so complicated?

- Lots of vehicles moving around for various purposes
- The scheduled tonnage must be executed on time to avoid production delays and profit margin shrinkage
- It's not an open free space… most tunnels are one vehicle wide!
- Queuing vehicles physically block tunnels… congestion!

≡ What is it all about?

- Determine where to position ore passes, truck chutes, etc.
- Determine how to smoothly mine stopes (material routing)
- For any year: how many vehicles of each type are required? What are the required passes, chutes and bins capacity?

More challenges

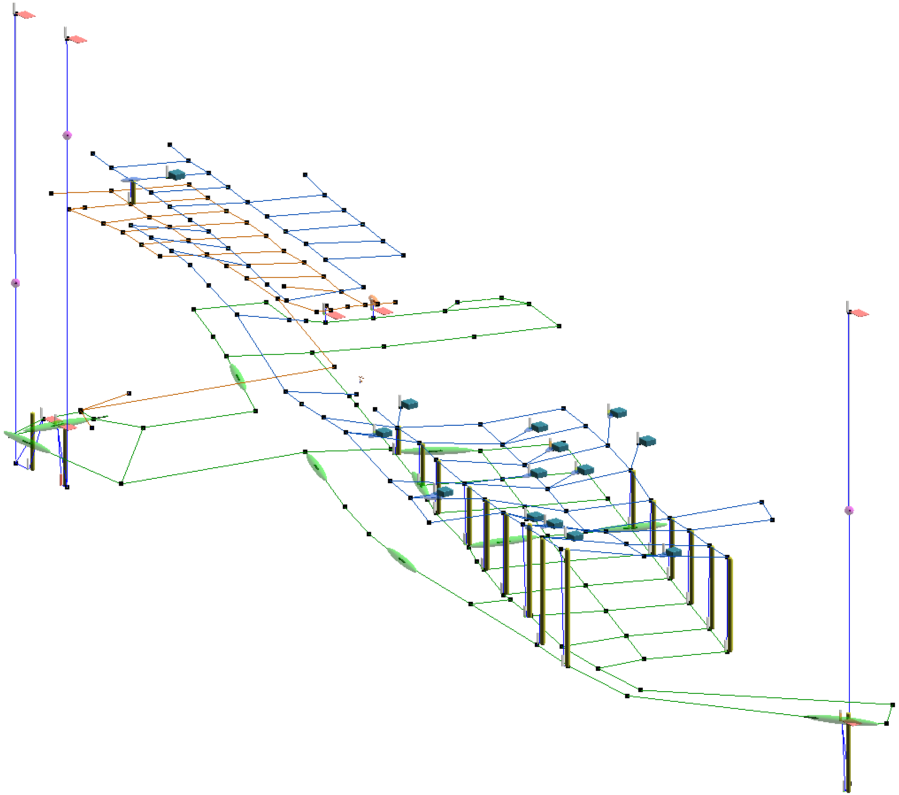
Many parameters to adjust simultaneously:

- Truck capacities and speeds
- Number of trucks of each type
- Priority rules to manage traffic
- Routing rules (material going from where to where)
- Location of intersections
- Location of ore passes and their capacities
- Sequencing of drifts development
- Fuel stations location and refuelling rules (avoid queuing)

... for every year of the life-of-mine plan!!!!

Visit of the model…

- The input…
- The model…
- The outputs…



Using the model

- Example of simulation-driven "discoveries"
  - Crushing rate is not fast enough because ore arrives in batches, not with a steady flow
  - Coarse ore bin is too small and blocks trains
  - Fine ore bin is way too big, over-design!
  - The required number of active LHD to achieve the budgeted tonnage exceeds the ventilation limitation
  - The refuelling schedule is inadequate: trucks wait 2 hours per day
  - Additional ore passes are required closer to the stopes to reduce LHDs travel time

How engineers had fun!

- During a 2-days session with the simulation:
  - Crushers were installed, relocated, resized
  - Ore passes were sank where they were not planned
  - Different truck types were purchased and tested
  - Trains switched from diesel to electric power
  - Second shaft sinking was executed 5 years earlier than planned
  - Operators were hired to replace drivers during lunch
  - Crusher control room was moved to surface
  - ….

Final words

If you ask yourself...

- Can the system attain its designed throughput?
- How can I scale up my production capacity?
- Are conveying and/or storage capacities adequate?
- Are there sufficient cranes or vehicles?
- Can the supply chain respond to client requirements?
- Is the schedule of operations feasible?
- What will be the impact of breakdowns on throughput?
- What are the optimal spare parts inventory levels?
- ..

Think Simulation!

In conclusion…

- Discrete Events Simulation is a powerful technique to model flow of items, schedules, operators tasks, and interactions between system elements
  - The exercise of building the model in itself brings to daylight **foreseeable** design flaws and operational inefficiencies
  - Simulation results helps to assess the impact of changes before really changing the system
  - A highly configurable model is a powerful and valuable support to engineering designs validation & optimization
  - Team consensus is built around an analytical tool…
- Simulation is beneficial to select solutions having a global impact!

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Powerful methods

Adapted approach

Combining harc work with fun

For more information, you can contact:

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