Supercharged Scheduling

How simulation can enhance scheduling
by avoiding
Lean waste

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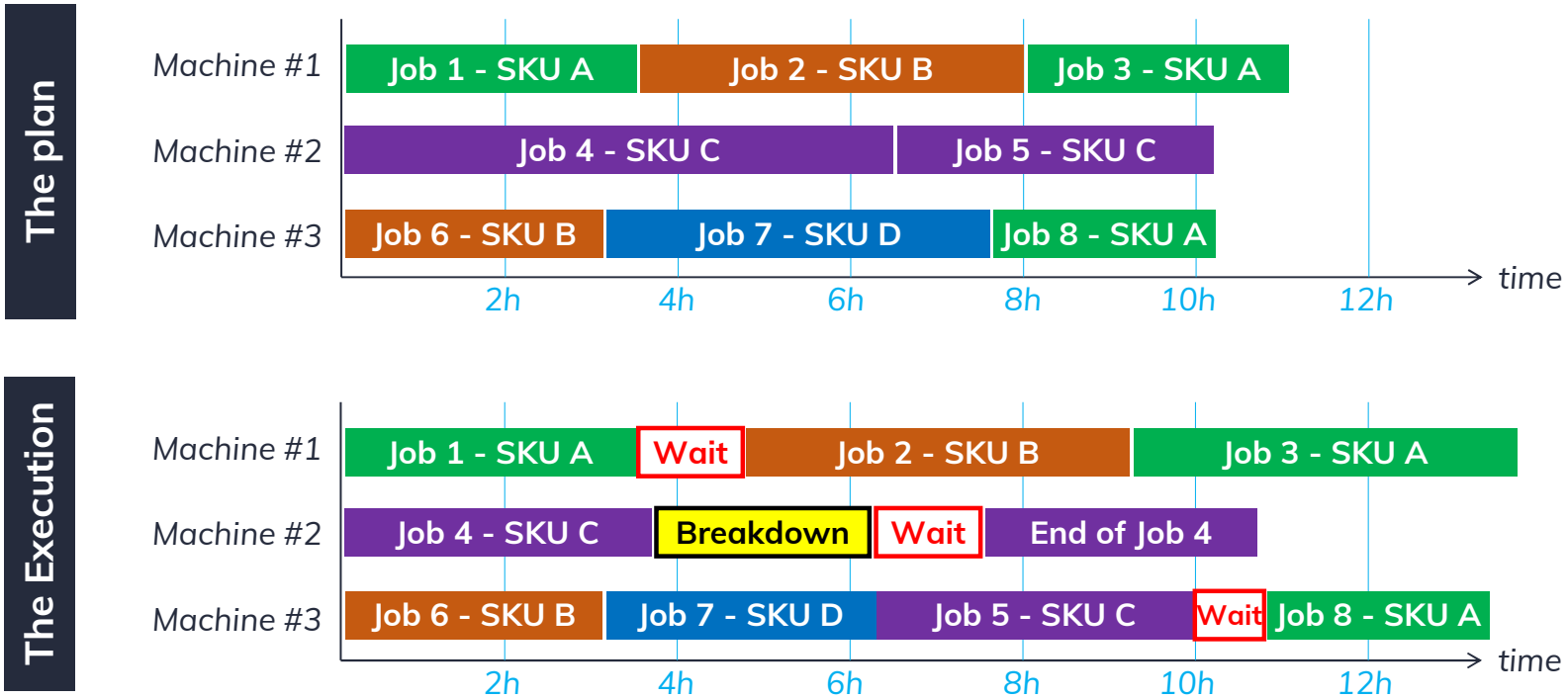
Presentation goal and content

- Understand why good schedules fail
- Discover Lean waste during planning
- Learn how simulation can reduce scheduling waste
- Illustration: a mine construction project
- Conclusion: valuable benefits

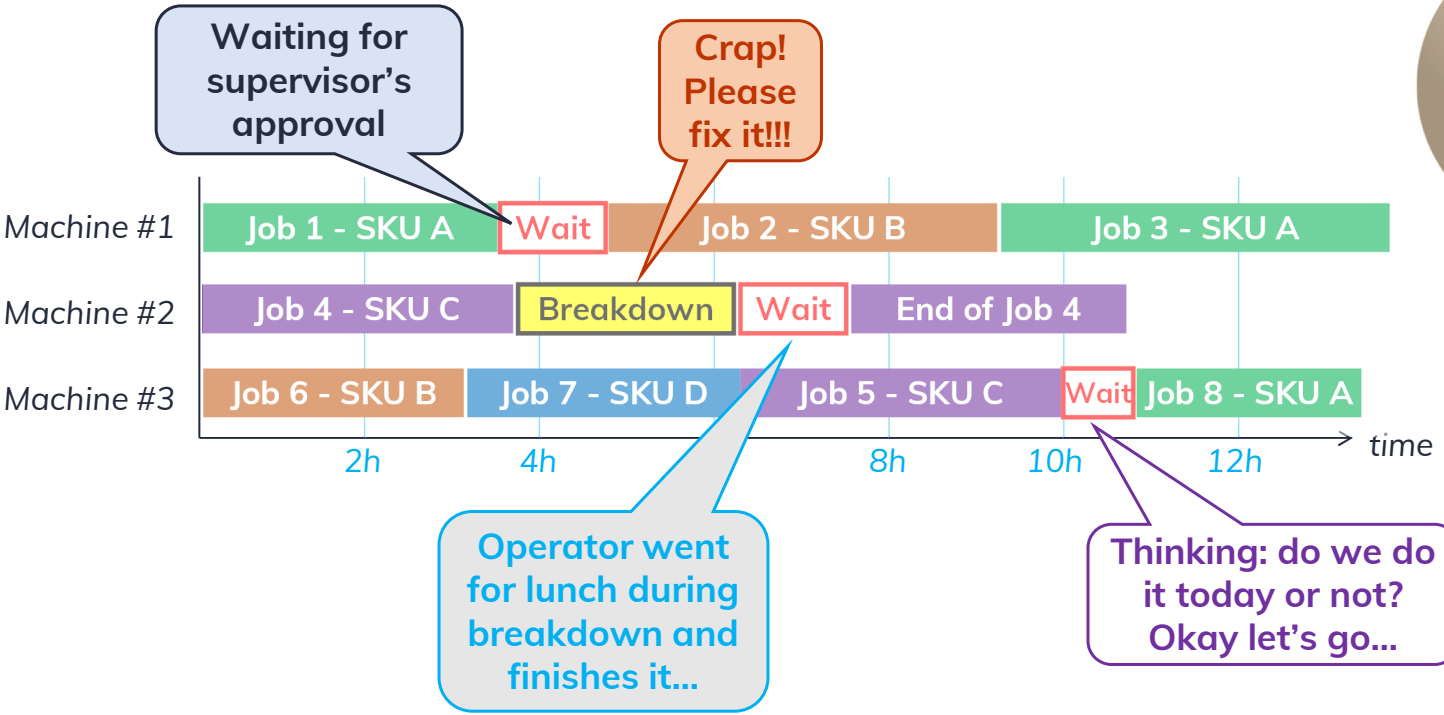
Open questions

- How do you manage production scheduling?
  - Software, humanware
  - Duration of the exercise
  - Etc.
- How satisfied are you with your schedules?
  - Deviance from original plans during production?
  - Any unplanned overtime required?
- Why do you think schedules are are often infeasible?

Frequent situation



Closer look at “The Execution”…



Were these part of “The Plan”?

≡ Waiting time because…

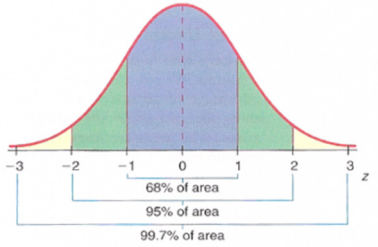
- Teammate went to pick tools/parts
- Changeover longer than expected
- No forklift available right now
- Upstream items did not arrive on time
- Quality inspector is busy somewhere else

≡ Delays because…

- Cycle time was longer than the “average”
- Have to travel between stations (was not planned)
- Process failures and machine breakdowns (weren’t they supposed to be 100% reliable?)

Variability kills plans!

- We typically plan using averages, but in real life durations vary around an average! Consequences:
  - Events don't happen exactly when expected/planned
  - Resources are queued for help and solutions
  - Unwanted buffers/inventories start piling up
  - Stress creeps in, switching to fire fighting …



How was “The Plan” made up?

- Computerized approach:
  - Team meets in a room for several hours
  - Averages are computed from the Big Data system
  - Excel spreadsheets are re-edited for the 1,000th time
    - "Oops… I messed up the formulas!”
    - “Oh no, external links are broken!!!”
- Many Lean wastes in this process!

Lost creativity

too busy, no time left to think for better ways

Waiting

Long time to generate a schedule, duration of reworks, bio breaks due to coffee consumption rate…

Defects

Calculation errors due to unreadable and un-debugable formulas

Over processing

Inefficient manual spreadsheet operations

Flashback!

≡ Remember the great ASQ event on April 24, 2019?

- Lean concepts: Mura, Muri and Muda
- Setup for failure: variability and over-utilization!

Defects

Transportation

Excessive inventory

Rush production to make the numbers

Employees are busy:
Managing defects
Pushing for speed
Managing inventory and WIP

Can we do better?

≡ Takeaways from the flashback :

- Don’t plan resource utilization at 100%
- Variability will happen (arrival rates, processing times)
- Buffers (queuing) will be needed!

≡ But, how can we consider when scheduling…

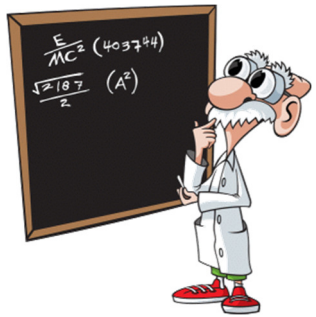
- Waiting time resulting of queuing for delayed parts, shared tools, operators, supervisors…
- Delays induced by lack of coordination between crew members
- Process failures and machine breakdowns depending of service hours, mileage or dynamic conditions

≡ Not in spreadsheets, obviously!

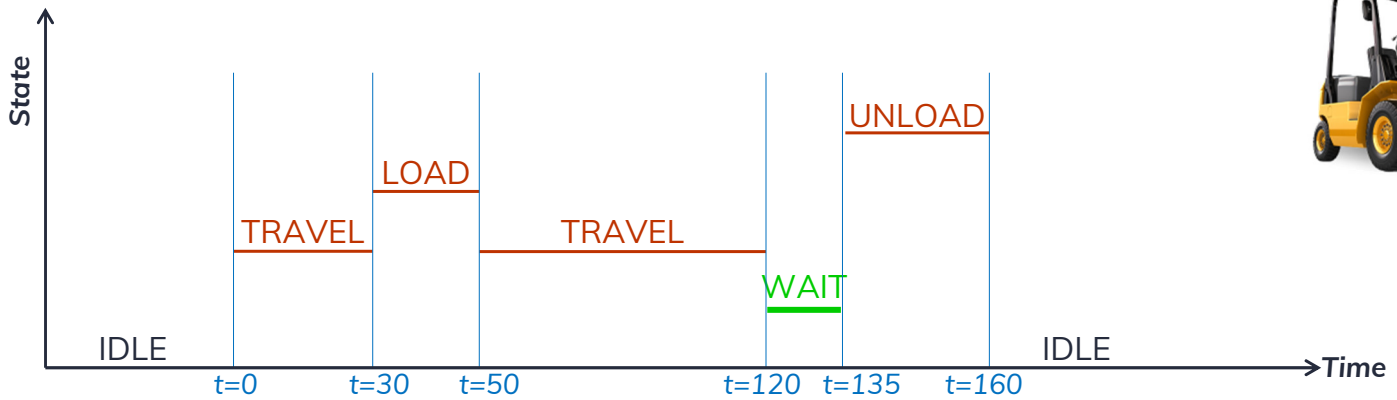
Then Comes
Discrete Events Simulation

Event-based modelling

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

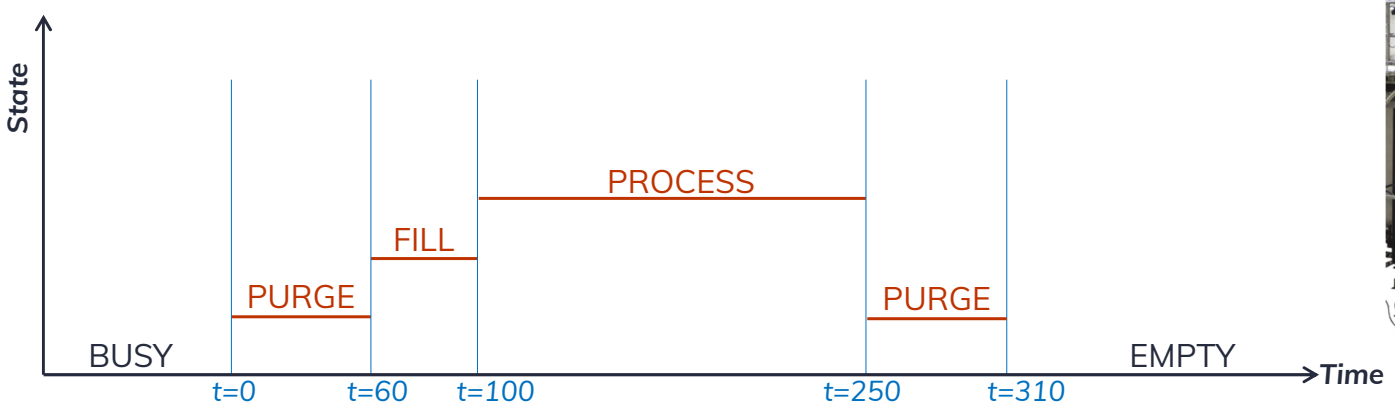


Example: moving a box



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

Example: sanitizing a tank



Tank to be cleaned! → Purge content → Fill with cleaning solution → Settling time → Purge solution → Cleaned tank!

Typical elements in a DES

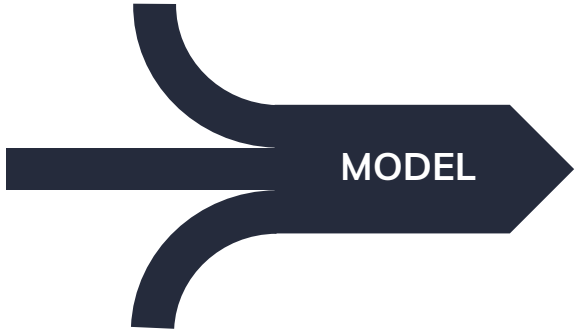
- All aspects of a production system describing or influencing flows, any element or constraint having an impact on overall performance
  - **Schedules**: daily shifts, weekly production, planned maintenance
  - **Equipment**: capacities, reliability, buffers, storage, conveying, piping
  - **Operators**: activities duration, task coordination, procedures
  - **Maintenance**: spare parts, work orders, repair times
  - **Transport**: mode, traffic, speed, loading times, queuing at intersections

DES = structured vision

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

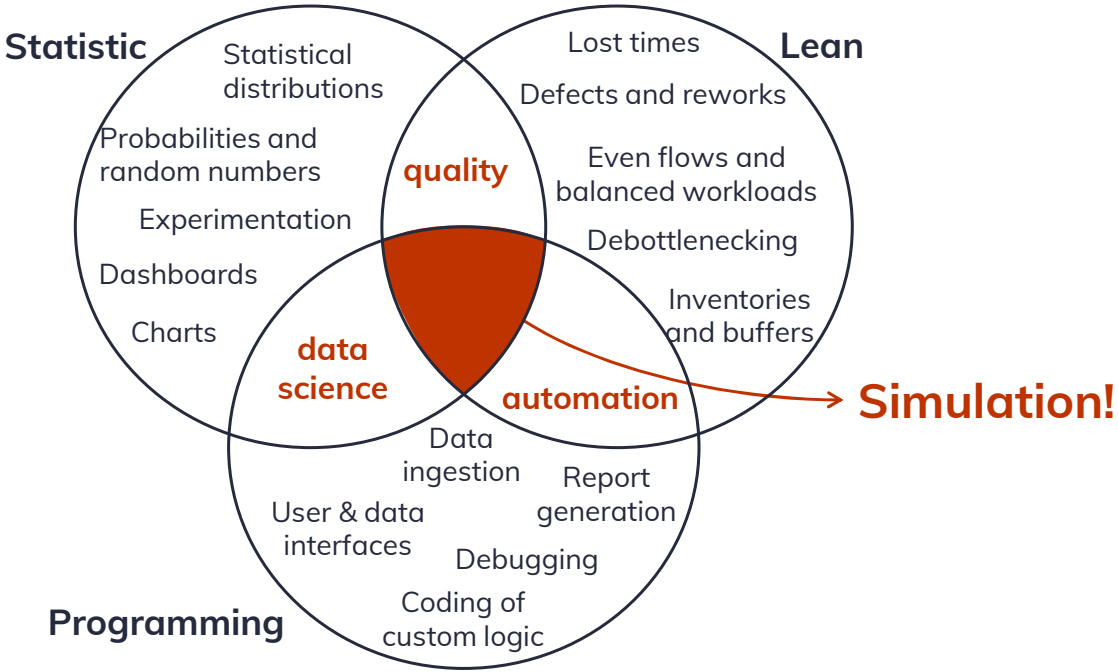
Outputs:

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

Experimentation
Optimization

Required skills to build DES

≡ Simulation is hard-bolted to Lean and Statistic!



Simulation-assisted scheduling

≡ Using simulation during a scheduling exercise:

Input from user

Production demand
(macro workload)

Pre-scheduling
(breakdown to bite-size jobs, generation of job sequences)

Knowledge from operations

Schedule validation
Simulation and predictive analytics!

Schedule optimization
Algorithmic or manual iterative improvements

Advises from experts

Output to user

Feasible "The Plan"

Illustration

The story of an underground mine construction

The context

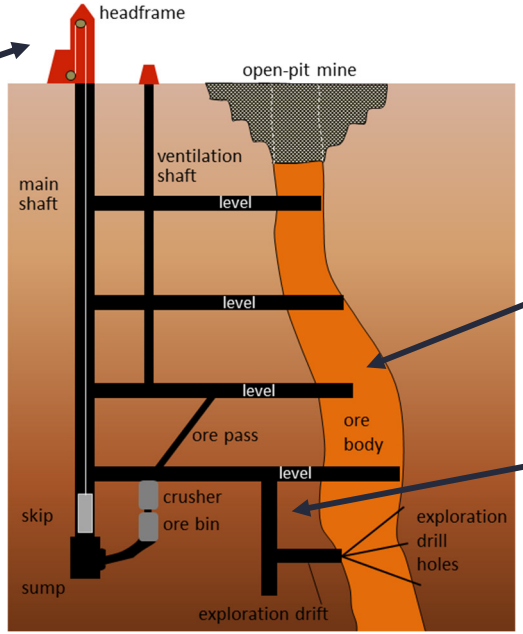
- Construction just started for a large underground mining project in central Canada
  - The ~10 G$ mine development should span over 5 years
  - Obvious signs that it will take more time than expected, we are already late
- But! All engineering disciplines made schedules!
  - Life-of-mine plan: how many tons from where and when
  - Development plan: which drift excavated for when
  - Procurement & logistics: when to bring what on site
- Commercial conflicts building up…

The context – visual aids

Procurement & logistics: bringing construction materials and equipment to headframe

Mystery #3
How the hell does all of that make its way underground?

Mystery #4
Did someone care about traffic through the shaft?



Mystery #1
Will routes to surface exist at the expected time?

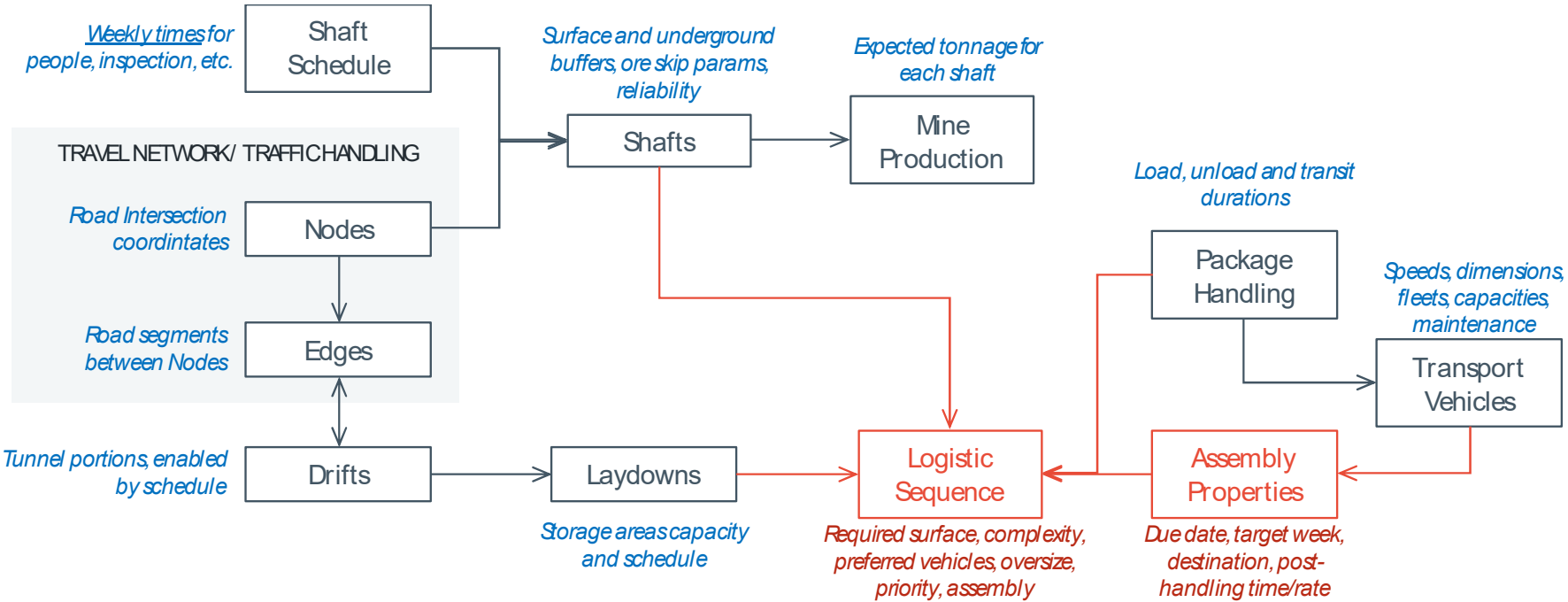
Life-of-mine plan: excavation schedule of the ore body

Development plan: excavation schedule of the levels and passes

Mystery #2
Will drifts be ready on time to receive from surface?

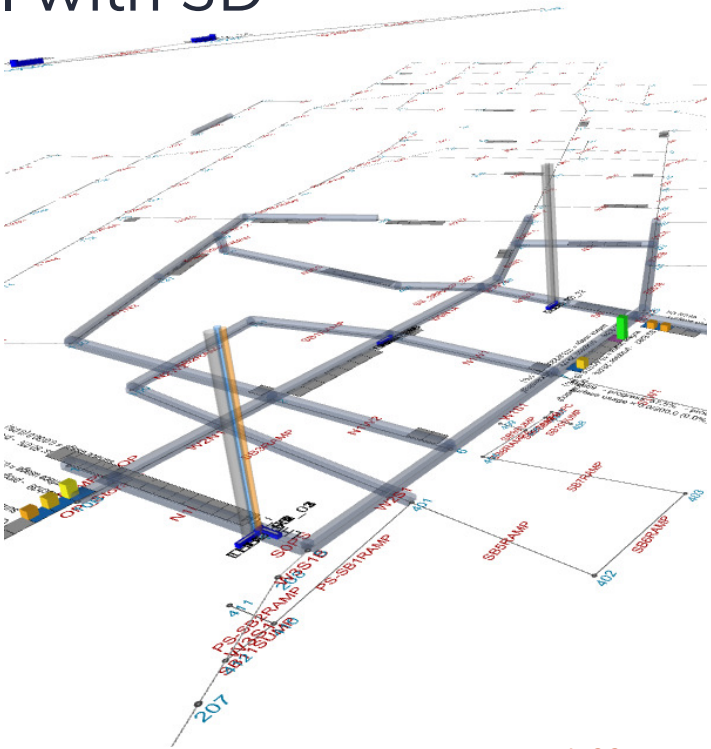
Shaft logistics simulation

≡ Many aspects to consider!



Shaft logistics simulation

- Discrete events simulation model with 3D animation to observe progress:
- Schedules, schedules:
  - Drift development
  - Mining rates
  - Daily shifts
  - Shaft & maintenance
  - Procurement



Shaft logistics simulation

Lots of input parameters....

Code	Active	Description	Type	Shaft	LoadShaft	HoistDuration	UnloadShaft	LoadVehicle
DV01	VRAI	Cage loads	SIMPLECAGE	DV	Triangular(1.2;1.6;2)	Triangular(2.5;3.3;3.9)	Triangular(1.2;1.6;2)	Bernoulli(0.25;5;2)
DV04	VRAI	Complexe Cage	TOUGHCAGE	DV	Triangular(30; 45; 60)	Triangular(2.5;3.3;3.9)	Triangular(30; 45; 60)	Lognormal(12;3;2)
DV02	VRAI	Simple slung loads	SIMPLESLING	DV	Triangular(13;15;17)	Triangular(2.5;3.3;3.9)	Triangular(13;15;17)	Bernoulli(0.60;5;15)
DV03	VRAI	Complex slung loads	TOUGHSLING	DV	Triangular(20.4;30.4;40.4)	Triangular(4.8;5.4;6.0)	Triangular(20.4;30.4;40.4)	Lognormal(12;3;2)
SS01	VRAI	Cage loads	SIMPLECAGE	SERVICE	Triangular(2.1;2.3;2.6)	Triangular(2.5;3.3;3.9)	Triangular(2.1;2.3;2.6)	Bernoulli(0.25;5;2)
SS04	VRAI	Complexe cage	TOUGHCAGE	SERVICE	Triangular(30; 45; 60)	Triangular(2.5;3.3;3.9)	Triangular(30; 45; 60)	Lognormal(12;3;2)
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EXPERIMENT | NODES | EDGES | DRIFTS | LAYDOWNS | SHAFTS | PACKHANDLING | PACKMOVE | WEEKLYSCHED | MINEPROD | ASSEMBLYF

... and lots of output results!

The scheduling Kaizen

≡ In the war room for 2 days:

- Experts representing each of the 3 disciplines
- Project manager for live decisions approval
- Simulation expert for live trials

≡ Simulation-assisted scheduling led to:

- Modify several laydown capacities and locations
- Modify drift development schedule (reduce waiting time)
- Swap many surface logistic sequences (proper timing)

≡ Achievements of this exercise:

- Catching up delays and finalizing construction in 5 years
- Bonus: possible path to make it 9 months earlier…

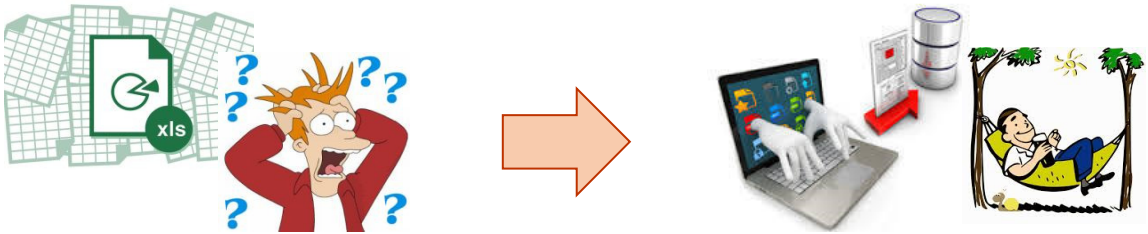
In conclusion

Valuable benefits

- From hours of teamwork to minutes by one person
  - What's your hourly rate? Manhours savings….
  - Can humans compete with machines calculation power?
- Optimized asset utilization
  - What's the cost of poor quality schedules? Think to re-scheduling effort, late order deliveries, etc.
  - What is the amount of waiting and down times due to improper load balancing and sequencing?
- Optimized people utilization
  - Stop spending hours crunching numbers – analyze charts and decide instead!

Valuable benefits

- Schedules tested against realistic jobs duration in real-world complexity
  - Know in advance what won't work!
  - Prepare weekly, revise daily… Foresee months ahead!
- Users participate to the optimization process
  - Iterations can be done manually – best use of experience!
  - Consensual decision tool – if team members don't agree on best strategies, just try them all!



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