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SIMULATION-BASED INTEGRATED DECISION SUPPORT TOOL FOR POTASH MINING OPERATIONS

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INTRODUCTION

Planning of potash mining operations requires consideration of many interacting machines, overlapping maintenance activities, layout of mine field as well as capacity of ore bunkers and conveyors. Integrated low-level simulation with user-friendly interface was developed to support monthly operations planning in Europe's largest potash producer. In this presentation, an example of using simulation in operations planning is given and created decision support tool is demonstrated. Main challenges that were met and overcome during development of simulation-based decision support tool are also discussed.

EXAMPLE OF OPERATIONS PLANNING CASE: WHERE TO SEND NEW ORE CAR

SKRU-1 mine has 11 combines working on 3 layers. The mine has 21 km of conveyor lines that transport ore to a single skip where ore is elevated to surface. Ore is excavated by mining machines (also called combines) and transported by ore cars to drop-off points. Each combine works with one ore car.

A new ore car with extended capacity (25 tons compared to capacity of existing cars of 12.5 tons) was purchased for $250 000. Management had to decide what existing car should be replaced with the new one to get the maximum production. Simulation was used to compare effects of using the new car to replace cars working with combines 1, 2, 4, 9 and 10. The results are shown on the Figure 1.

Option #	Index of combine that works with the new car	Increase* of avg. daily combine performance (ton/day), %	Increase* of overall mine production volume (tons of ore per month), %
1	2	+29,57%	+3,26%
2	1	+21,24%	+2,67%
3	10	+8,09%	+1,10%
4	4	+3,59%	+0,32%
5	9	+3,12%	+0,31%
*Compared to the case where no new car is used			

Figure 1: Effects of using new car to replace existing cars working with different combines

Simulation showed that the best option is to replace car working with combine #2. This would give +3.26% increase of monthly production of the mine, or +2 800 tons of finished product in June 2014. Worst option would be to replace car working with combine #9, this would give only +1 126 tons of finished product. The decisions similar to the one described above are taken every month during operations planning.

STANDARD AGENT-BASED FUNCTIONALITY OF ANYLOGIC WAS EXTENDED

Combines and ore cars are modeled as agents that are moving in mine network which is represented by a directed weighted graph. AnyLogic has built-in functionality for modeling agents, but it lacks support of spatial relationships of agent with network and with other agents.

Figure 2 shows several situations that occur in mining process and have to be modeled because they significantly influence overall mine performance. Implementation of these cases is not directly supported in AnyLogic and would require much low-level programming.

The decision was made to create Agent Graph Library – an additional layer of logic between the built-in AnyLogic agents and core logic of mining model. The main features of this library include:

- Tracking and handling of agents' collisions
- Support of graph arcs weights changing over time
- Support of moving one agent to another moving agent
- Ability to handle events of passing certain points in graph
- Measuring of distances between agents along the shortest paths in graph

Agent Graph Library allowed modelers to concentrate on core model logic and has been reused in several models for different industries.

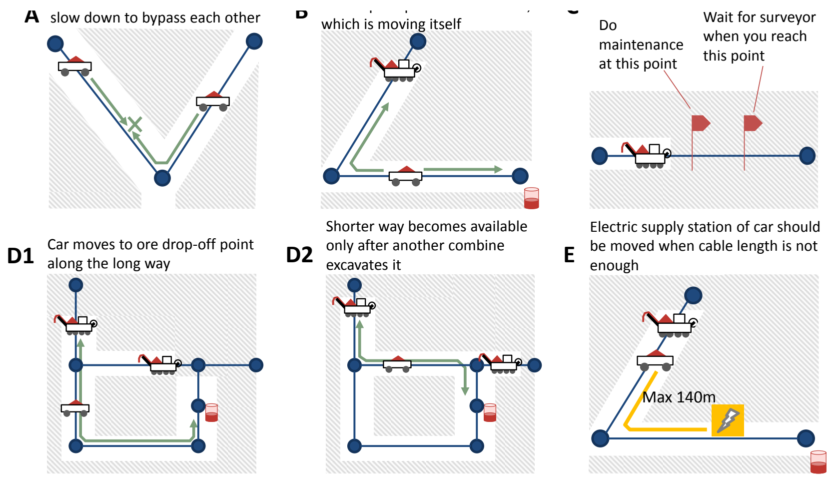

Figure 2: Cases that lead to technical difficulties in implementation

DISCRETE-RATE LIBRARY WAS DEVELOPED FOR MODELING ORE FLOWS

After excavation, ore is transported to surface through the system of bunkers and conveyors. These bunkers and conveyors have limited capacity and often become bottlenecks, so modeling of continuous ore flows that are moving through mine becomes necessary. It is reasonable to model ore flows with discrete rate approach which is not supported in AnyLogic out-of-the-box. The idea of this approach is that instead of splitting model time into slices and recalculating system state at each time slice, only the moments of rate changes are considered.

In this case study, discrete rate approach was implemented in Discrete Rate Library that allows modelers to build flow diagram from blocks that are connected by flow connection points. The fragment of such diagram that was used to model ore bunker is shown in Figure 3.

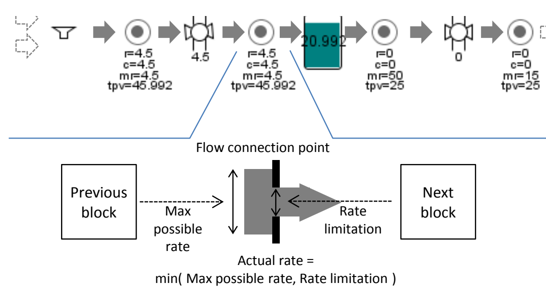

Figure 3: Modeling ore bunker with blocks of Discrete Rate Library

Flow connection points connect consecutive blocks. Maximum possible rate is propagated forward (along flow direction) from the previous block, and rate limitation is propagated backward from the next block to the previous one. Actual rate at connection point is calculated as minimum of these two values.

Apart from flow connection points, the library contains 6 blocks: Tank, Pipe, Merge, Valve, FlowSource and FlowSink. The library saved effort needed to implement mining process model and can be reused in any AnyLogic model that considers continuous material flows.

CONCLUSION

During the project, AnyLogic modeling framework was extended with two reusable libraries for modeling complex interaction of agents and continuous material flows. The simulation-based decision support tool is used for monthly production planning, identification and avoidance of potential process bottlenecks as well as mine workers' KPIs calculation.