

A general digital twin driving mining innovation through statistical and logical modelling

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Partners

Örebro University-Mechanical Engineering, Umeå University-Computing Science, Epiroc Rock Drills AB, Kaunis Iron AB, MinProc Analys AB

Project duration

2022 - 2025



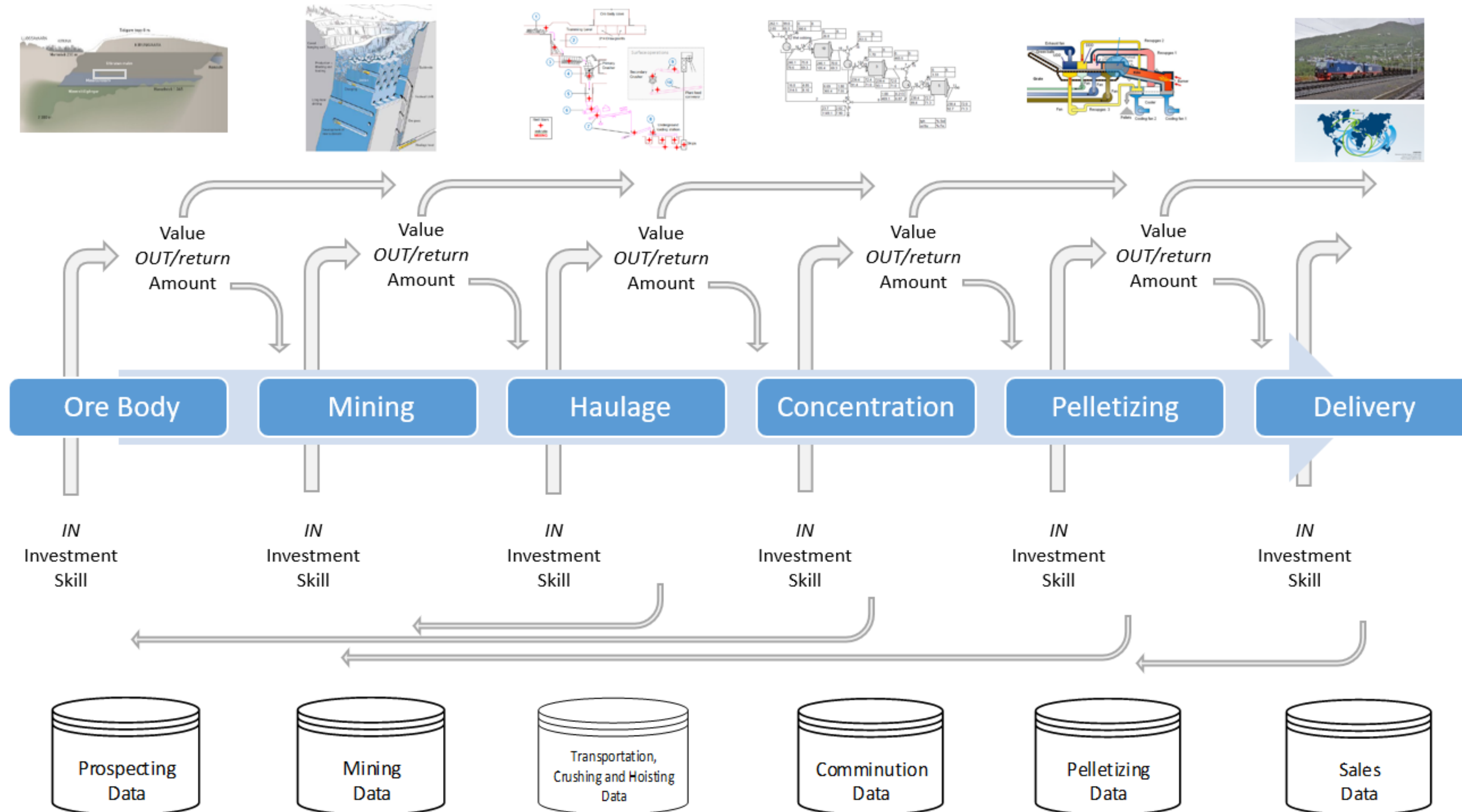
Goals of the project

The goal with the DT-MINN project is to improve ecological and economical sustainability in terms of extraction of raw materials, through development of decision support to operate a mine as efficiently as possible.

- Digital twin platform for production process availability prediction and maintenance optimisation
- Interfaces between the above systems and between these systems and primarily Epiroc machinery in the Kaunis IT infrastructure and production process
- Information and process models for the above



The complex mining value chain requires well-structured data for analytics, including maintenance

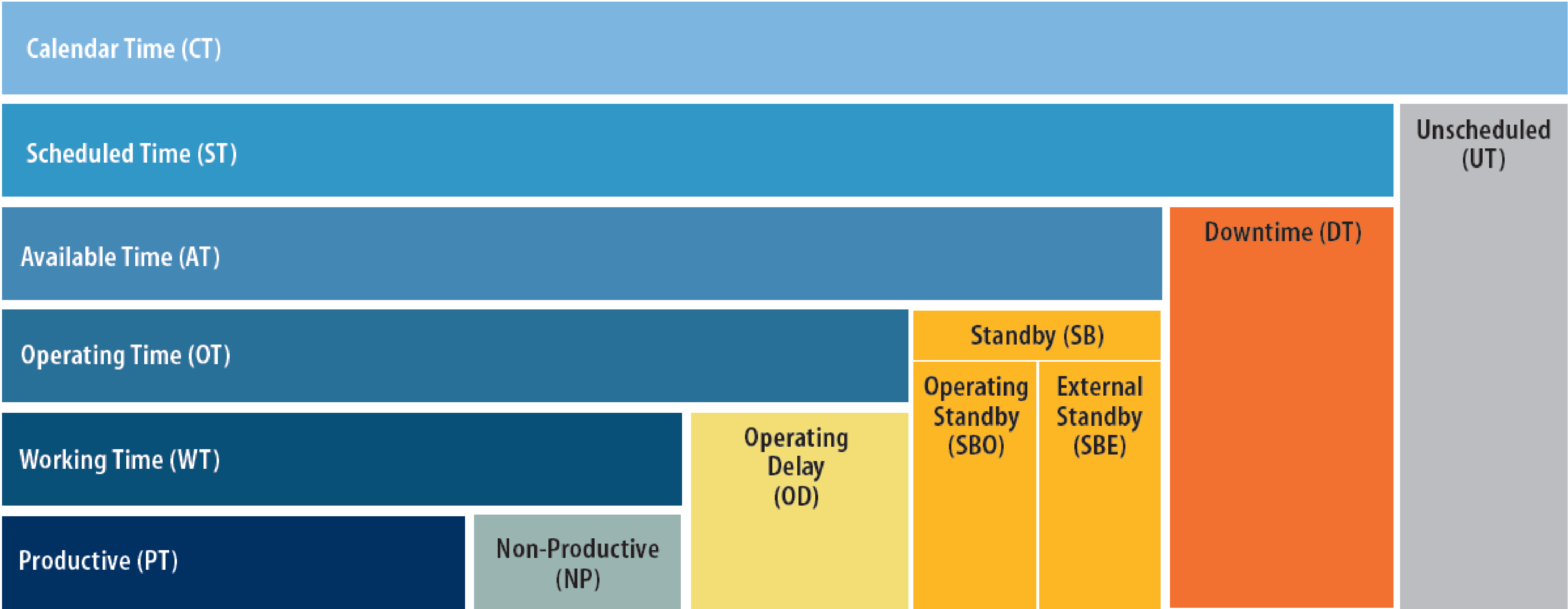


GMG

A STANDARDIZED TIME CLASSIFICATION FRAMEWORK FOR MOBILE EQUIPMENT IN SURFACE MINING: Operational Definitions, Time Usage Model, and Key Performance Indicators

SysML model of GMG’s Time Usage Model (TUM)

We can now create good synthetic / simulated time-stamped data for up-scaling the Kaunis / Epiroc case for general fleet management and maintenace inc. mining.



The GMG guideline covers the most common surface mining **activities**, associated **status** and **event** descriptions, and the time categories needed to classify the activities and generate the most widely used mining operational KPIs.

Results

- Statistically based simulation approaches developed for predicting event outcomes developed, using GMG's (Global Mining Guidelines Group) *STANDARDIZED TIME CLASSIFICATION FRAMEWORK FOR MOBILE EQUIPMENT*
- Process and information models being developed, relating Epiroc machinery to mining production processes
- Data structuring is standards based
- General methods for improving system uptime under development

New contacts for future research applications developed at SMI events.



Results

1. Satyam, P., Turnbull, R., Khodadad, D. & Löfstrand, M. (2022). A Vibration Based Automatic Fault Detection Scheme for Drilling Process Using Type-2 Fuzzy Logic. *Algorithms*, 15 (8).
2. P. Eklund, U. Höhle, *Finite quantales and applications*, LINZ2022, 39th Linz Seminar on Fuzzy Set Theory, Linz, Austria, February 7-10, 2022.
3. A. Shamsgovara, *A catalogue of every quantale of order up to 9*, 39th Linz Seminar on Fuzzy Set Theory, Linz, Austria, February 7-10, 2022.
4. Reed, Sean, Löfstrand, Magnus; *Discrete Event Simulation Using Distributional Random Forests to Model Event Outcomes*, Winter Simulation Conference, Singapore, December 11-14, 2022.
5. P. Eklund, *Assessment computations involve numeric and symbolic values*, IGI Global, chapter
6. S. Reed, M. Lofstrand, J. Andrews, *Modelling stochastic behaviour in simulation digital twins through neural nets*, *Journal of Simulation* 16 (5), 512-525, 2022
7. Shamsgovara, A. (2023). *Enumerating, Cataloguing and Classifying All Quantales on up to Nine Elements*. *Relational and Algebraic Methods in Computer Science*. RAMiCS 2023. Lecture Notes in Computer Science, vol 13896. Springer, Cham.
8. S. Reed, M. Löfstrand, *Efficient Estimation of Survival Signatures through Simulation with Depth-First Search of Indices*, European Safety and Reliability Conference ESREL 2024, June 23-27 2024, Jagiellonian University, Cracow, Poland.
9. Satyam, P. , Turnbull, R. , Khodadad, D. & Löfstrand, M. (2022). A Vibration Based Automatic Fault Detection Scheme for Drilling Process Using Type-2 Fuzzy Logic. *Algorithms*, 15 (8).
10. Eklund, P. , Kortelainen, J. & Löfstrand, M. (2025). Quantales for Fuzzy Sets and Relations of Higher Types. *Mathematics*, 13 (13).
11. Vinayak Patil, R. & Löfstrand, M. (2025). Detection and Classification of Engine Exhaust Weld Joint Defects Using RNN and SVM on SS316L–SS410 and SS310–SS410. *Journal of Failure Analysis and Prevention*.

Results

- Dr. Sean Reed employed (part time)
- Dr. Satyam Paul employed
- Dr. Rajesh Patil employed

KK Foundation Avans project awarded for developing a *two-year mechanical engineering master program* data driven product and production development at Örebro University

DT-MINN project feeds into the ongoing KKS Avans new master project at Örebro University, *Data-Driven Product and Production Development*

Upcoming activities and next step

- Partner meetings during Fall 2025 to prepare for continuation/extension project
- 4 - 5 publications in development
- Planning for new funding applications to continue development is under way
- Plans for further expansion of the research group
- Project meeting with the offshoot KKS Avans project during Fall 2025



Mining innovation for a sustainable future