Tampere University

Industrialization of 16T Nb3Sn magnet production for HE-LHC and FCC

FCC WEEK 2019, Brussels, Belgium

Ananda Chakraborti, Suraj Panicker, Eric Coatanéa, Kari T. Koskinen
Automation and Mechanical Engineering Dept.
Tampere University (TAU), Finland
Email: ananda.chakraborti@tuni.fi
Phone: (+358) 413692130

Contents

Introduction

- Cost-effective manufacturing of Nb3Sn magnets for FCC and HE-LHC can be achieved by optimization of current HL-LHC magnet manufacturing performance using *key performance indicators (KPI)*
- Statistical modeling and simulation of Nb3Sn manufacturing system (winding house)
- Surrogate-based analysis and optimization of manufacturing systems with Dimensional Analysis Conceptual Modeling (DACM[1]) framework and Bayesian Networks

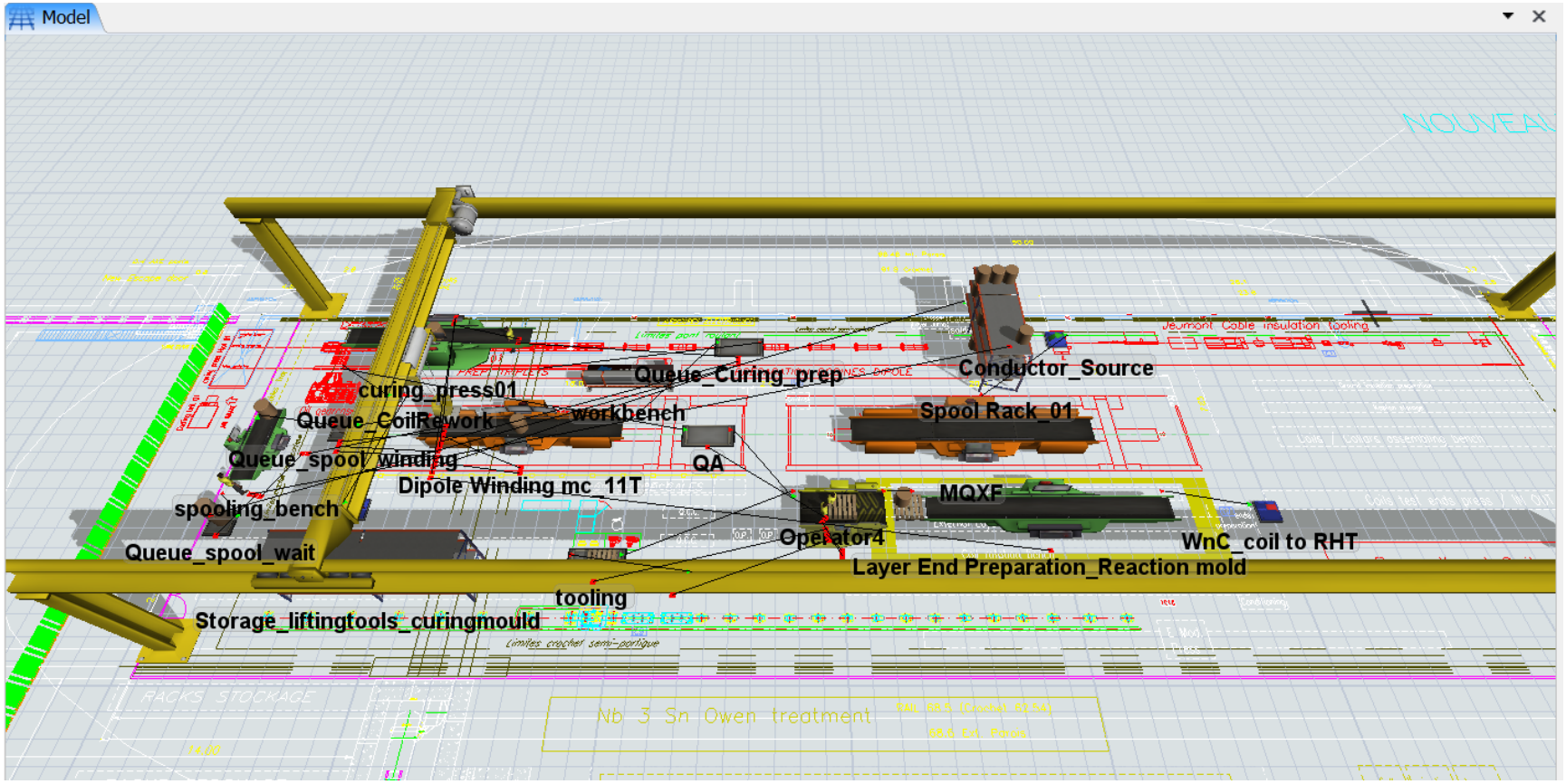
[1] Coatanéa, E., Roca, R., Mokhtarian, H., Mokammel, F., & Ikkala, K. (2016). A conceptual modeling and simulation framework for system design. Computing in Science & Engineering, 18(4), 42-52

Tampere University

Statistical M&S of Nb3Sn magnet manufacturing system

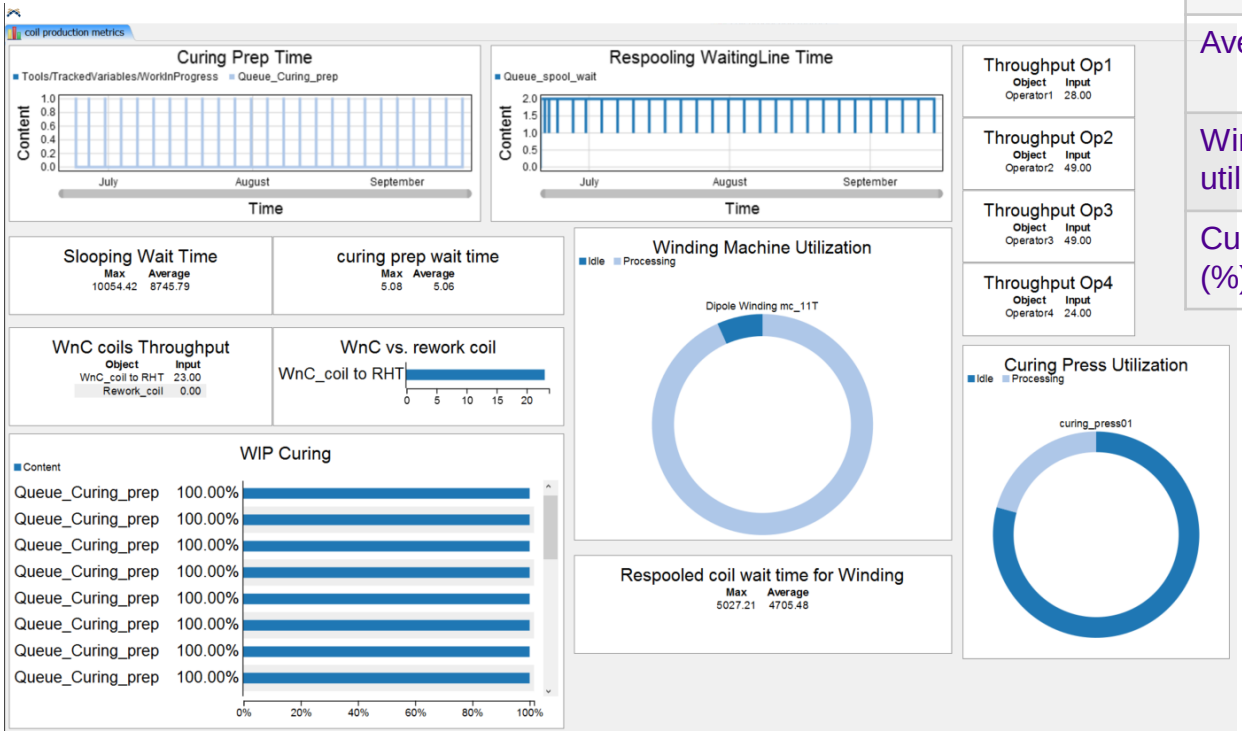
Winding house simulation at LMF

Statistical modeling of Nb3Sn magnet manufacturing (11 T dipole – winding house)



Time data as per coil no- HCMBH_C005-CR000007 (2017)

Simulation Results



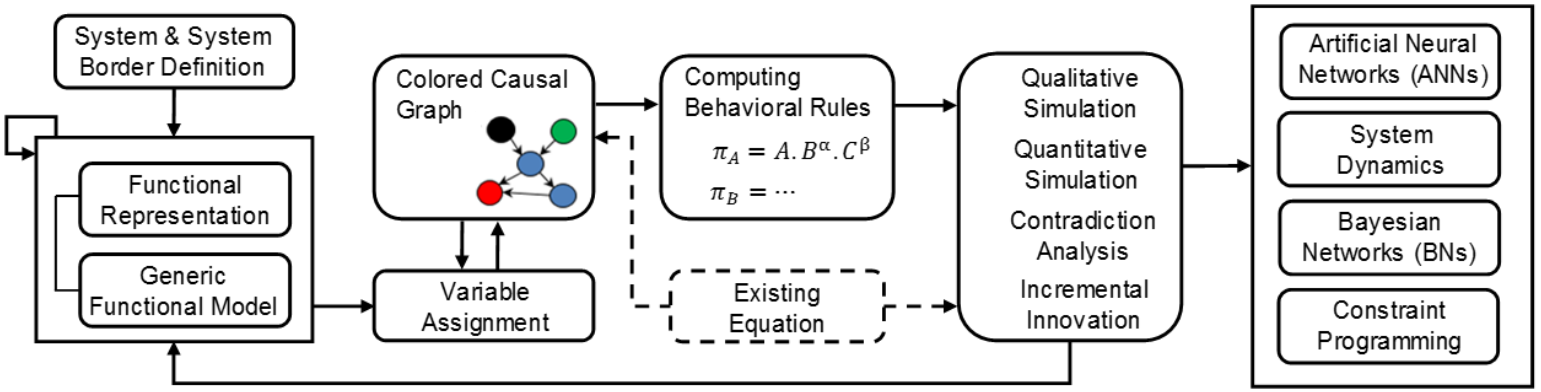
WnC process parameters	Results
Estimated process throughput (coils)	23
Average winding time (hrs)	83.738
Winding machine utilization (%)	93.32
Curing press utilization (%)	79.29

Tampere University

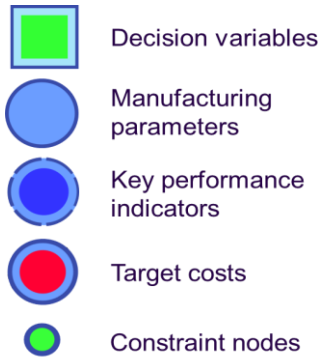
Surrogate-based analysis and optimization of Manufacturing Systems with DACM Framework and Bayesian Networks (BN)

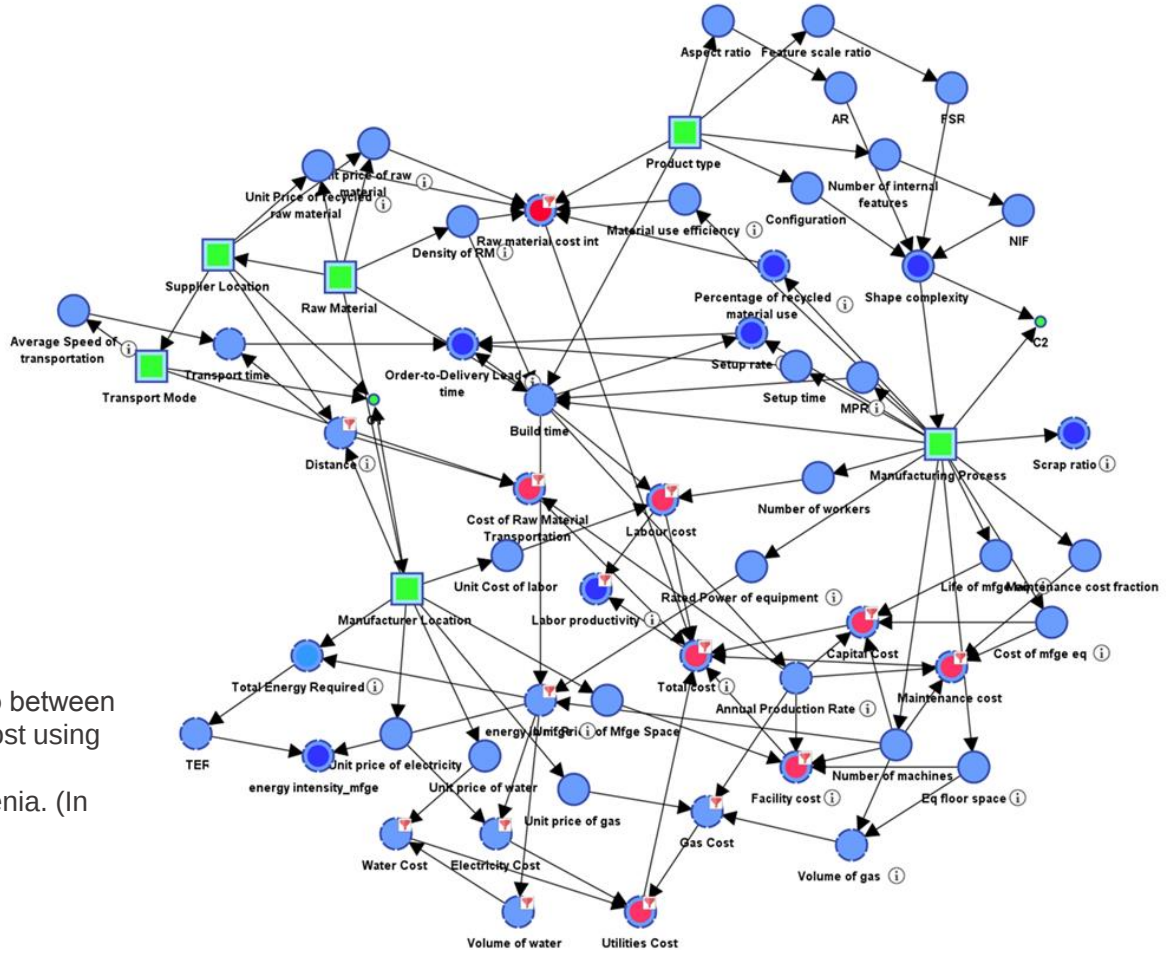
DACM Framework

- DACM is a conceptual modeling mechanism for complex systems
- The main goal of DACM is to extract and encode knowledge of different forms in the system with the help of causal representation
- DACM has been successfully applied to case studies in the domain of additive manufacturing (AM), product design and multidisciplinary design optimization (MDO)



Probabilistic Cost Models with BN

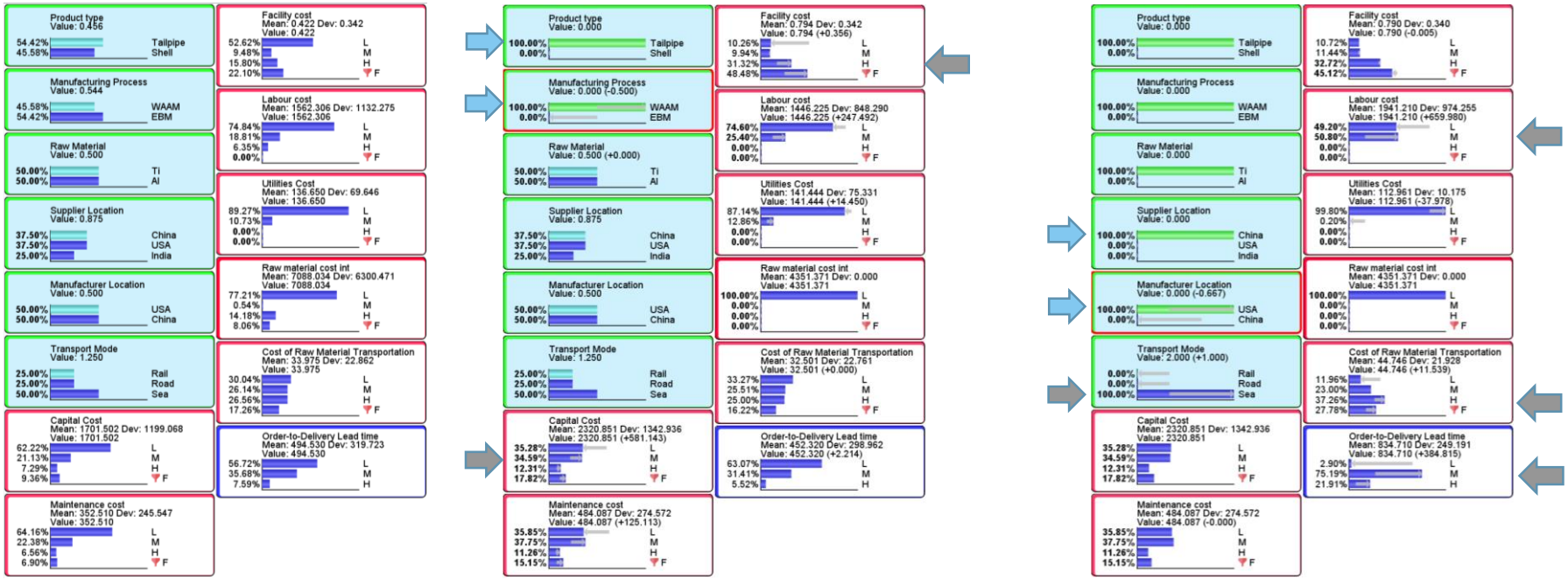




S. Panicker et al., “Tracing the Interrelationship between Key Performance Indicators and Production Cost using Bayesian Networks” in CIRP Conference on Manufacturing Systems 2019 , Ljubljana, Slovenia. (In press)

Results

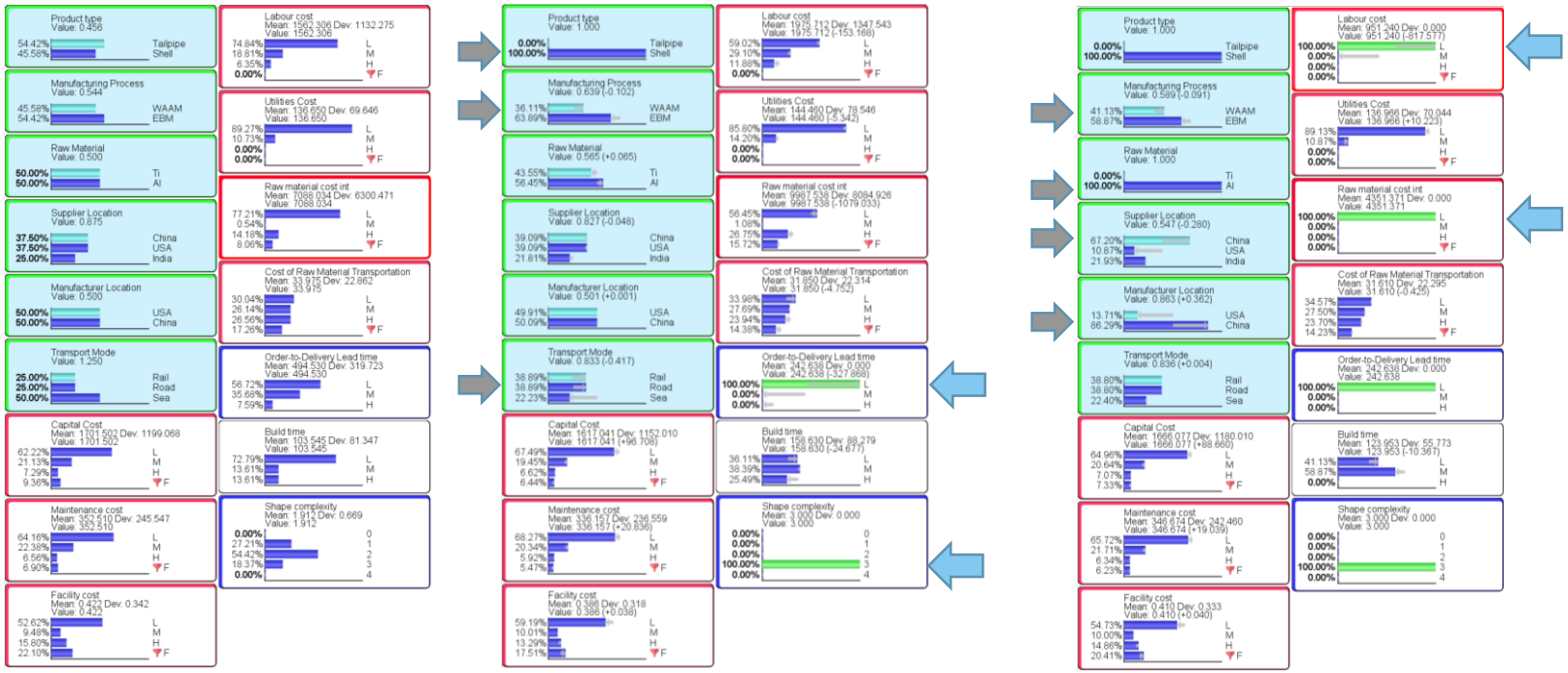
Manufacturing Decisions → Effect on performance targets



Results Contd.

Suggested manufacturing decisions

Predefined performance targets



Dimensionality Reduction

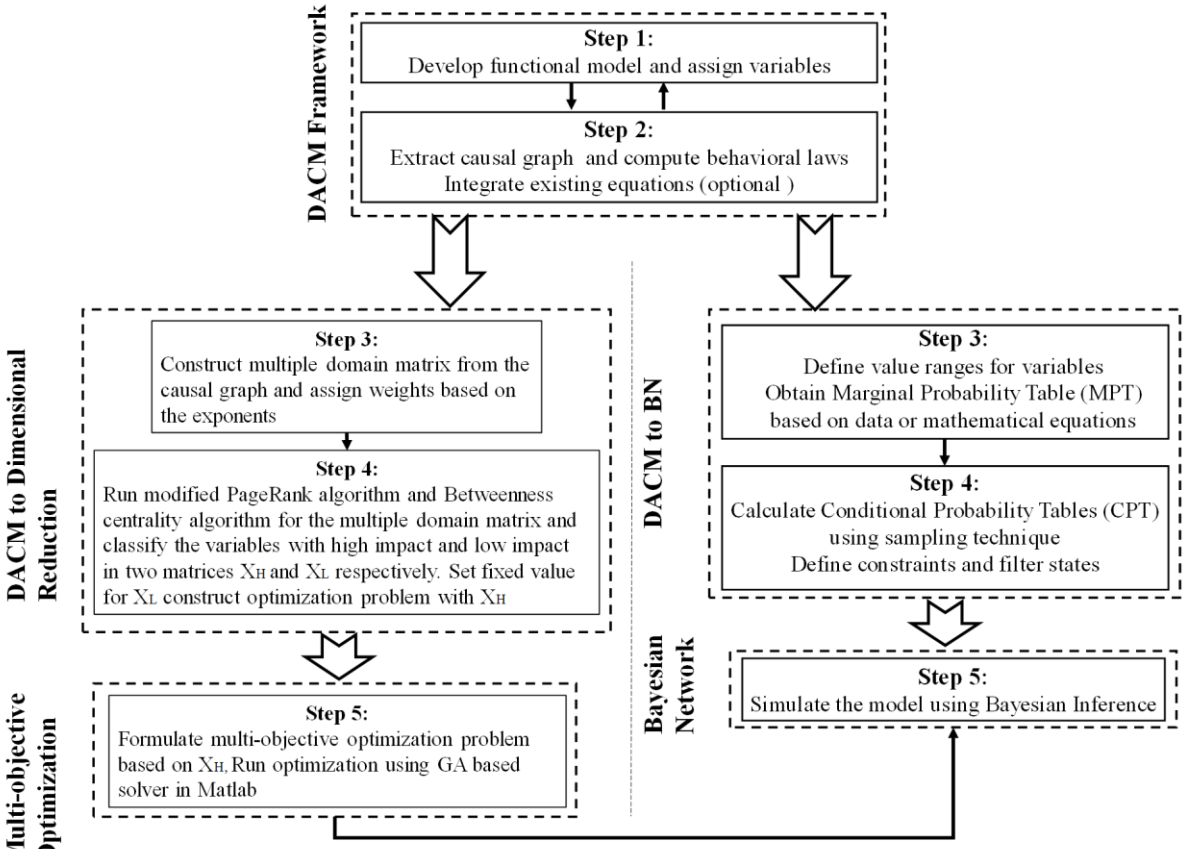
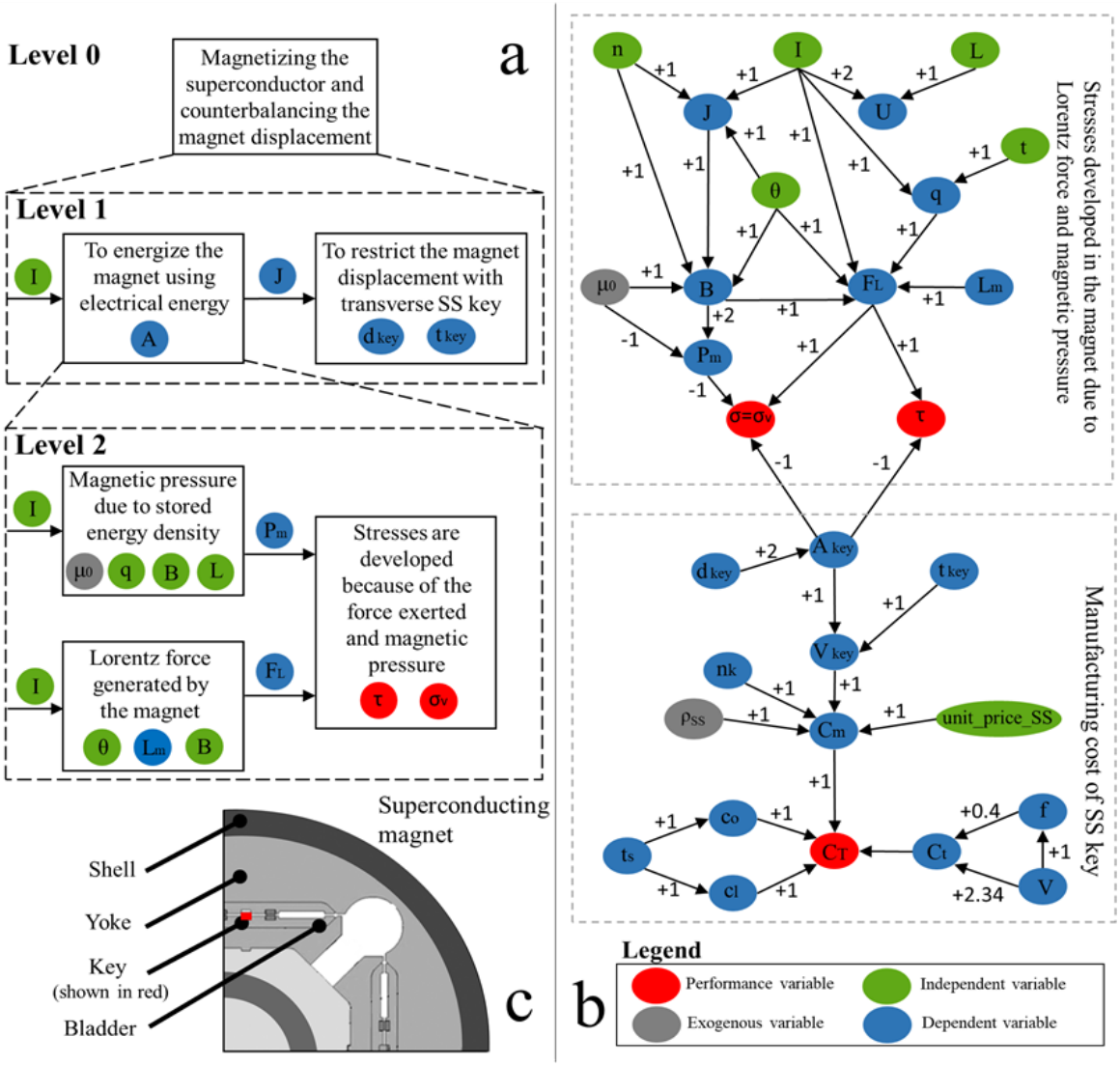


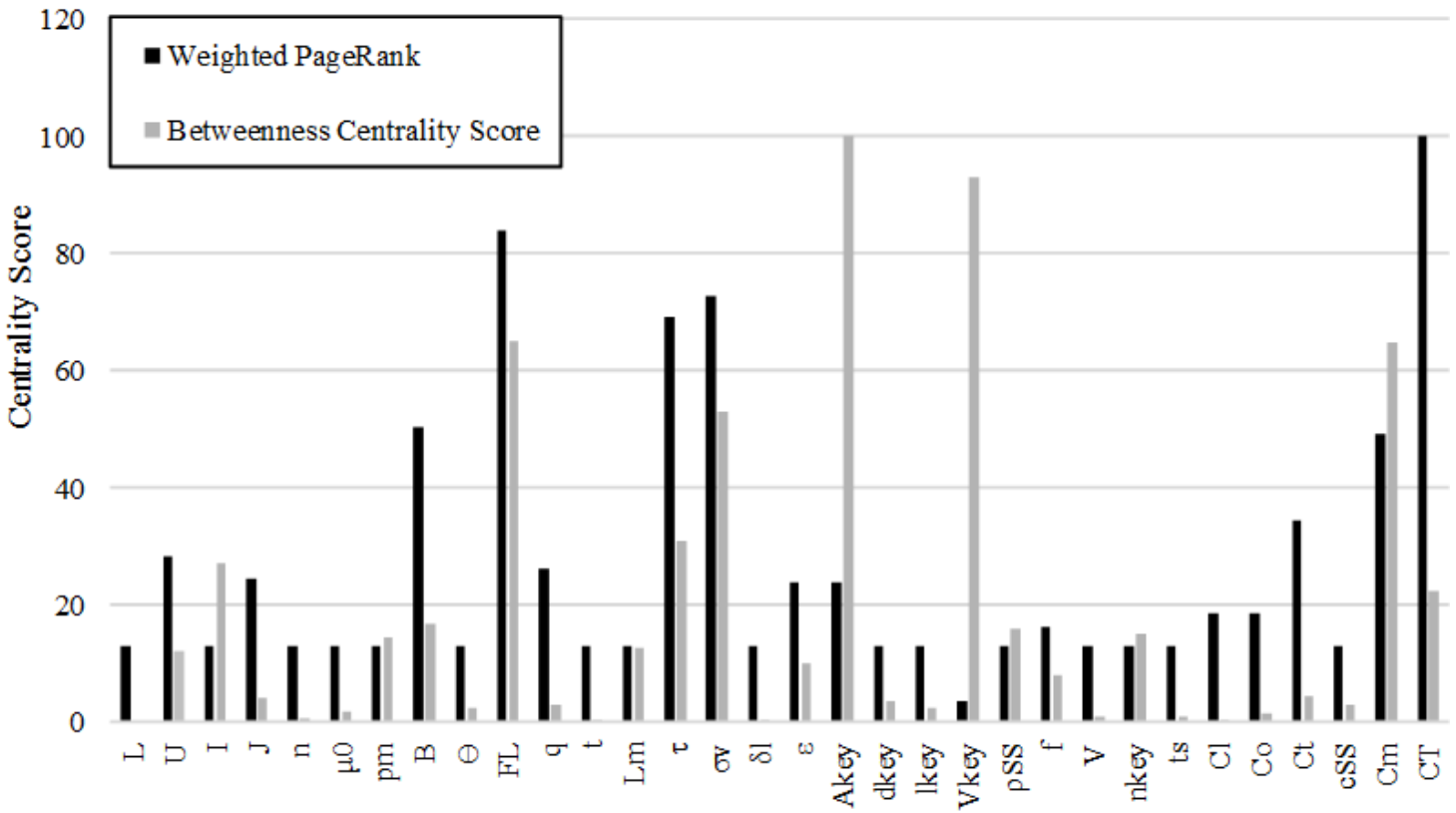
Figure 1: Combined framework for the developed methodologies

abstract

fidelity



A. Chakraborti et al., “A Dimension Reduction Method for Efficient Optimization of Manufacturing Performance” in 29th International Conference on Flexible Automation and Intelligent Manufacturing (FAIM 2019), Limerick, Ireland. (In press)

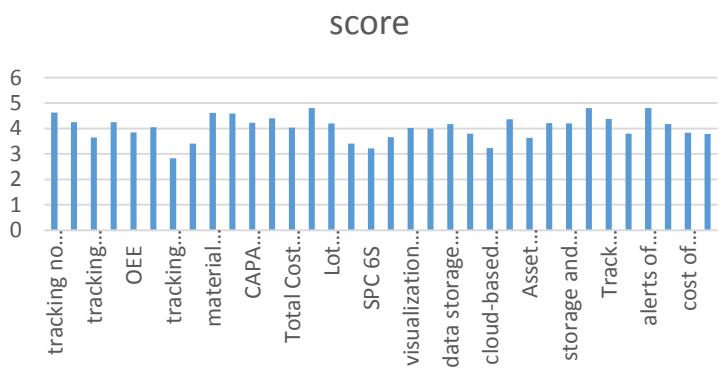


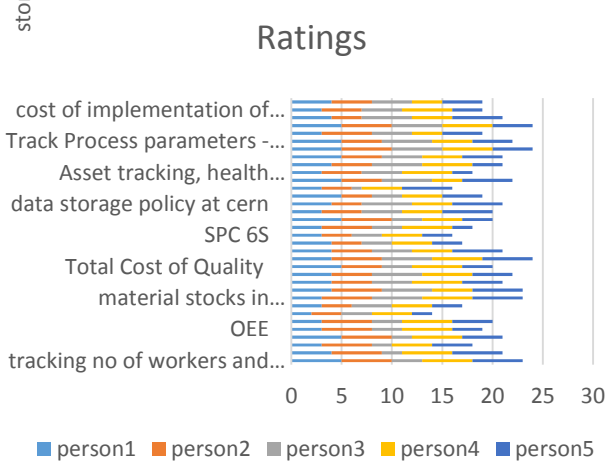
Graph centrality scores

Tampere University

Adoption of Industry 4.0 tools and techniques in magnet production

Need for digitalization in HL-LHC production

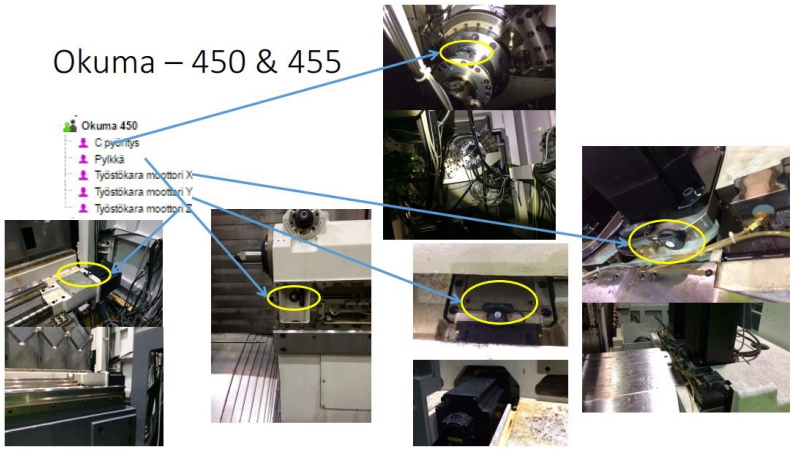




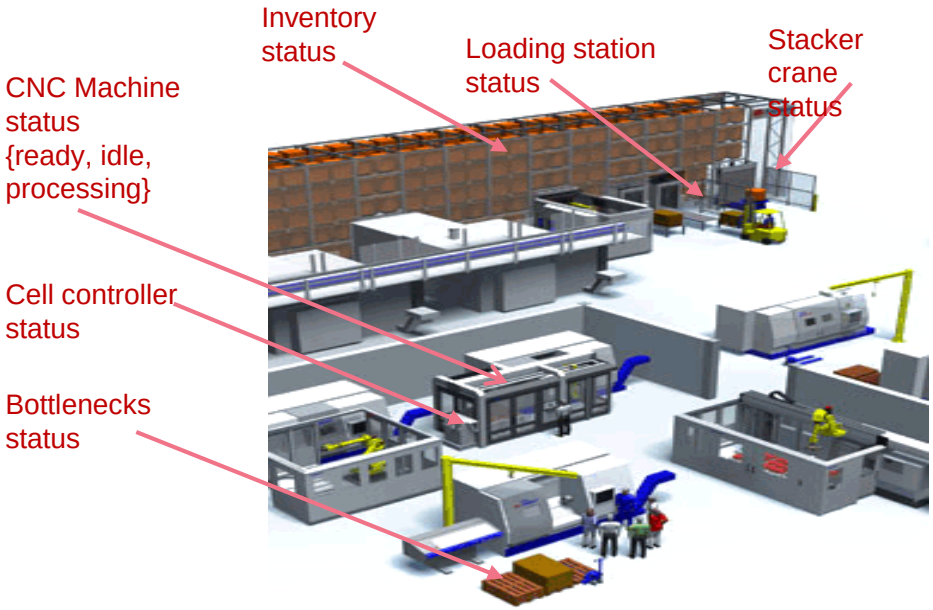
1	Tracking stock levels of all magnet parts
2	Tracking critical coil quality parameters
3	Alerting process variations
4	Tracking of total man hours spent per magnet
5	Integration with existing IT infrastructure

Top 5 functionalities according to interview scores

- Complete traceability of components
- Production process status info (in phases)
- Detailed production cost breakdown
- Live status of the device: running, idle, off-line
- Quality risks, reliability of delivery related risks
- Anomaly detection



Flowtag installations in production for machine vibration tracking – example form a pilot case in Finland



Production visualization – example from a pilot case study in Finland

Conclusion

- Statistical modeling and simulation of Nb3Sn magnet manufacturing is conducted to predict coil production parameters
- Surrogate-based analysis and optimization models for manufacturing cost are built and tested with various case studies
- Adoption of Industry 4.0 tools and techniques in SC magnet production are discussed