

VARIETY IN VARIABILITY IN HEAVY CIVIL ENGINEERING

Anne Fischer, Niklas Grimm,
Iris D. Tommelein, Stephan Kessler, and Johannes
Fottner

AGENDA

- Introduction
- Purpose of this paper
- Related work
- Sources of variability
- Industry 4.0 tools to address variability
- Conclusions

INTRODUCTION

- **Industry 4.0** [1] challenges the construction industry to adopt digital technologies in order to address its **ever-increasing complexity** [2].
- Pure **adaptation** of technologies does not optimize a process [3].
- One needs to define **sources of variability** in a system to identify the adjustments that can be made in order to manage or even improve the system [4].

[1] Lasi, H., Fettke, P., Kemper, H.-G., Feld T., and Hoffmann, M. (2014) "Industrie 4.0." *Bus. Inf. Syst. Eng.*, 6(4), 239-242.

[2] McKinsey (2017). Reinventing Construction: A route to higher productivity. McKinsey Global Institute, www.mckinsey.com/mgi (March 31, 2021).

[3] Lander, E., and Liker, J.K. (2007). "The Toyota Production System and art: making highly customized and creative products the Toyota way." *Int. J. of Production Research*, 45(16), 3681-3698, DOI: 10.1080/00207540701223519.

[4] Tommelein, I.D. (2000). "Impact of Variability and Uncertainty on Product and Process Development." ASCE, Proc. Construction Congress VI, 20-22 Feb., Orlando, Florida, USA, 969-976, DOI: 10.1061/40475(278)101.

PURPOSE OF THIS PAPER

- *What are characteristics concerning the application of lean principles?*
 - *Which variabilities influence the Kelly drilling production?*
 - *How may these be addressed by Industry 4.0?*
- Semi-structured **interviews** are conducted
- Results are compared with estimating production rates of **earthmoving** literature.

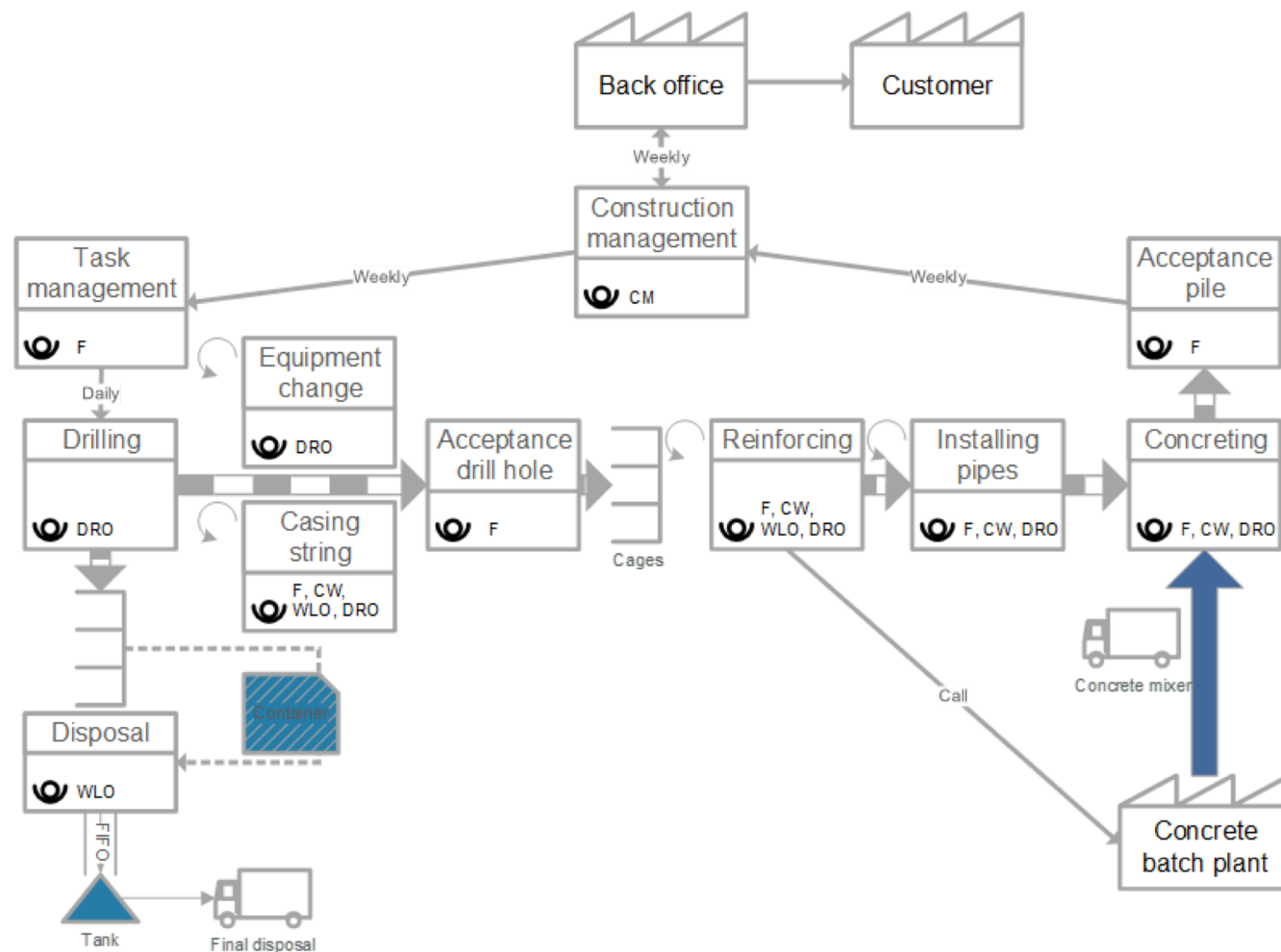


Figure 1. Rotary drilling rig at test site of Bauer Group in Schrobenhausen, Germany (Pictures by Fischer, A.)

RELATED WORK

- **Multi-story construction** deals as much with the sharing of resources as it does with the interdependence between them.
- **Earthworks** focus is on fleet interaction
- **Foundation-pile production** have been isolated and limited as a one-piece flow line dependent on single machine due to high complexity
- **Characteristics of variability in product and process [4]:**
 - Product is defined by its parts, e.g. functionality, configuration, and geometry.
 - Process is defined by its activities, e.g. resource assignment and sequencing of activities.

PILE PRODUCTION USING KELLY METHOD



CM: Construction Manager

F: Foreman

CW: Construction Worker

DRO: Drilling Rig Operator

WLO Wheel Loader Operator

Figure 2. Value stream map

SOURCES OF VARIABILITY

Variability	Digital model	IoT	AI	Simulation	Appropriate technologies help...
1. Contractual requirements	X			X	gain a better understanding by visualization.
2. Environmental influences			X	X	handle weather forecasts.
3. Site organization	X	X		X	visualize and test site logistics in advance.
4. Geology	X		X	X	visualize the single soil layers to improve reaction time.
5. Operator skill		X	X	X	track and analyze personnel's performances.
6. Operating conditions		X		X	monitor and virtually test routing strategies.
7. Abrasion and failure			X	X	predictive maintenance and capture stochastic failure.

Table 1. Variabilities in relation to Industry 4.0 tools

INDUSTRY 4.0 TOOLS

Variability	Digital model	IoT	AI	Simulation	Appropriate technologies help...
1. Contractual requirements	X			X	gain a better understanding by visualization.
2. Environmental influences			X	X	handle weather forecasts.
3. Site organization	X	X		X	visualize and test site logistics in advance.
4. Geology	X		X	X	visualize the single soil layers to improve reaction time.
5. Operator skill		X	X	X	track and analyze personnel's performances.
6. Operating conditions		X		X	monitor and virtually test routing strategies.
7. Abrasion and failure			X	X	predictive maintenance and capture stochastic failure.

Table 1. Variabilities in relation to Industry 4.0 tools

CONCLUSIONS

A comparison with earthmovings and expert interviews reveal **7 sources of variability** and derived recommendations.



Process improvements will depend not solely on Industry 4.0 tools but on improvements in the **socio-technical system**.



Implementation of **lean principles** and standard **workflows** serve as a basis for adaptive **simulation studies** to capture variability.



THANK YOU!

Anne Fischer, M. Sc.

anne.fischer@tum.de

Technical University of Munich
TUM Department of Mechanical Engineering
Chair of Materials Handling, Material Flow, Logistics

