Methods of artificial intelligence in procurement

Review, practical application, and future research

HICL Ph.D. Seminar digitally on September 21st, 2021

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Advised by Prof. Dr. Heiner Stuckenschmidt and Prof. Dr. Christoph Bode

About the researcher Jan Martin Spreitzenbarth

First doctoral employee in the Porsche procurement division

Key facts

- Since 2018 External doctoral student in the Data and Web Science Group at University of Mannheim
  Supervised by Prof. Dr. Heiner Struckenschmidt with support of Prof. Dr. Christoph Bode

- Research interest in the **application of artificial intelligence and machine learning in procurement**
  First paper predicting TCO for supplier selection (ERS 2020 / AACE 2021)
  Second paper review of AI and ML in procurement (IPSERA 2021) vs sales (ERS and HICL 2021)
  Third paper simulation workflow (ISDC 2021) with bundling module (EurOMA 2021)

- Since 2016 Buyer at Porsche for infotainment, embedded software, currently requirement management
  Led by Thomas Pichler and Stephanie Bach, sponsored by Joachim Scharnagl

Last stations in the CV before joining Porsche

2014 - 2015 **Post-graduate scholarship with German Academic Exchange Service DAAD in China**
Language study in Beijing and IT consultant for an Industry 4.0 project (Smart Factory)

2012 - 2014 **Master degree at Karlsruhe Institute of Technology with IBM in Germany**
MSc in industrial engineering and project buyer of smart meters in Mainz (Smart Home / Smart Energy)

2011 - 2012 **Gap year at Robert Bosch in Germany**
Logistics planner for solenoid valves and metering units at plastics engineering plant in Waiblingen

2009 - 2011 **Bachelor degree at Simpson College in the USA**
Intern at a local automotive supplier in Iowa as well as for an United States Senator in Washington, D.C.

Interests

- Team sports e.g. soccer, basketball, and volleyball
- Travel, languages, and cultures especially Asia
- Nature, hiking, climbing, wine, and horticulture

I am looking forward to an interesting discussion with you today!

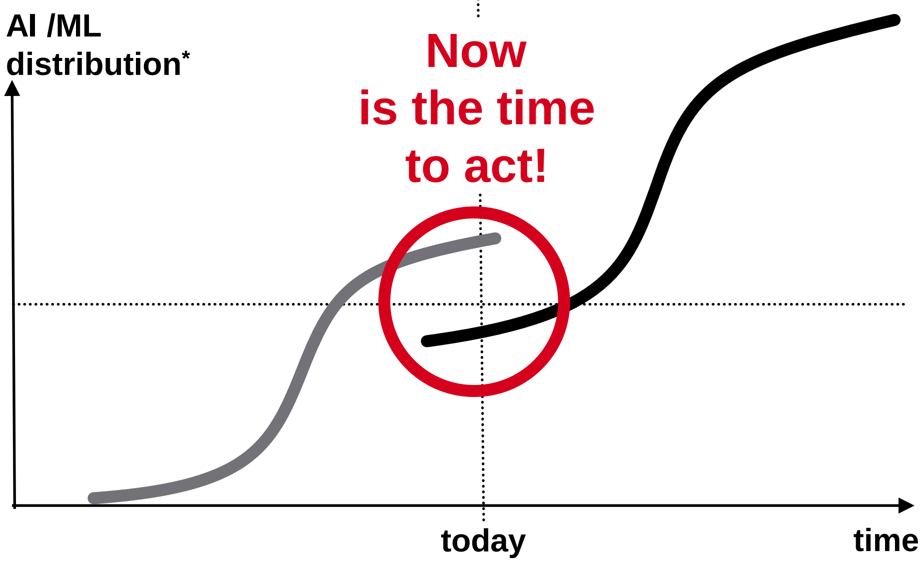
Note: AI=artificial intelligence, ML=machine learning, TCO=total cost of ownership

Artificial intelligence, now is the time to act!

AI and ML methods offer potential for practical implementation

THEORY — APPLICATION

AI / ML research | **AI / ML practice**



Four factors have changed in recent years, allowing use of AI and ML in business

Data availability
Massive growth of data available

Free software
Open source simplifies implementation

Faster hardware
Technical development enable new applications

Availability of services
Digital providers offer partial AI solutions already

Reality	Long-term research	Science Fiction
"Weak AI"	"General AI"	"Super AI"
Assistance or acquisition of specific tasks with individual solutions	**Knowledge transfer** from single solutions to larger topics	Machines are able to **meet people spiritually**

Application of AI and ML are coming out from research into practice.

Source: AI@Porsche project team * According to a typical trajectory for the introduction and adoption of new technologies.

Summary Ph.D. at KI conference doctoral workshop 2021

Interdisciplinary research AI for business

Overarching RQ: **How** to **utilize** the **potential of AI and ML in procurement**?
Focus on **OM community** with **intersection to information systems**

#1 Case study TCO prediction (How?)

#2 Review+ Procurement versus sales (Why?)

#3 Model Simulation optimization (How?)

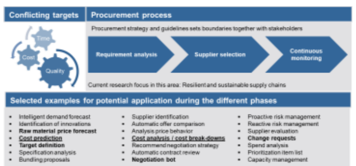
#2 Review Describe the current body of knowledge highlighting the potential (What?)

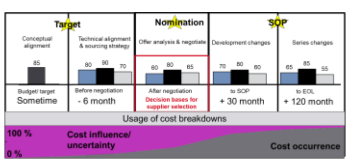
Ph.D. summary presented at HICL DC ☺

Study I framework for TCO analysis case study

Data for different sources is used to conduct the study

Analyze





Draft

Pre-study

Pre-study with N= 2.157 of 2015 - 2018 mainly in the area of non-production materials and different eClasses →Understand cost drivers for further data collection

Intersection analysis

Negotiation result & performance
→Cost planning & target bot

N= 19.127 of 2012 - 2019 from production materials from nomination data bases

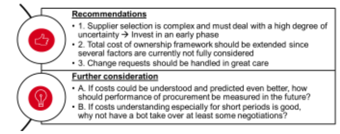
Utilize cost breakdowns
→Cost transparency over the lifecycle

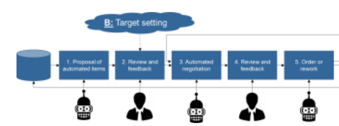
N= 199 of 2015 - 2020 from production and non-production materials

Consider change requests
→Consider in nomination & plausibility

N= 1.586 of 2012 - 2019 from production materials mainly from high level change management board and of different types

Evaluate





Data from different sources, use cases, and types based on a pre-study.

Note: Due to time restrictions, the presentation has been optimized for the format, four further slides are included in the deck and further details are included in the working draft.

Study I case study results of cost prediction quality

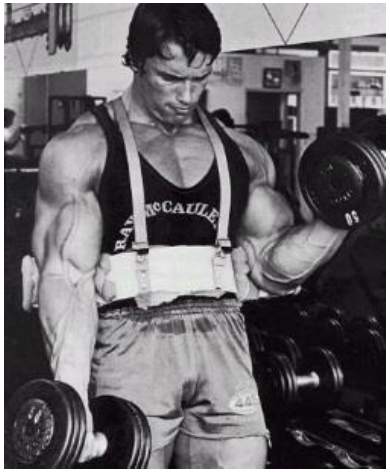
Mean, standard deviation (SD), and mean magnitude relative error (MMRE)

Data has been split into 70 % training and 30 % test set

Data set	Naïve baseline			Logistic regression			Regression trees			Bayesian optimization		
	Mean	SD	MMRE	Mean	SD	MMRE	Mean	SD	MMRE	Mean	SD	MMRE
Intersection	-3.2	6.4	32 %	-4.0	3.7	21 %	-3.7	2.6	17 %	- 3.6	2.2	**12 %**

<u>Next steps:</u>

1. Train and optimize models, e.g. bagging or boosting
2. Compare with others methods and studies, i.e. 25 % MMRE considered good for early software cost estimation
3. Plug the results back in the TCO equation



AI models perform well, at least compared with baseline and regression.

Source: Laderia, 2002. Note: R version 3.6.2 on Mac and Windows used from https://www.r-project.org/foundation.

Study II literature review AI and ML methods in procurement

Overview of the study

Background

AI and ML techniques are recently **starting to emerge** in **procurement theory and practice worldwide.**

Based on literature reviews of big data analytics in supply chain management, there is a need to review the literature **focusing specifically** on **artificial intelligence** and **machine learning in procurement**.

The work started off as a systematic literature and become more of a conceptual literature review over time.

Methodology

Content analysis approach by **Mayring**:

1. **Material collection**, which entails a process of search and delimitation of articles
2. **Descriptive analysis**, which provides characteristics of the studied literature
3. **Category selection**, which aims to construct a classification framework

Followed by the **material evaluation**, additionally **20 expert interviews** conducted to assess the **business value** and the **ease of implementation**.

Results

210 publications were identified, described and classified based on the **strategic**, **tactical** and **operational level of procurement** and according to the **ACM computing classification system**.

Summarized the **state-of-the-art** in **theory enriched** with **practical ideas,** made **available** for **further research**.

11 use case clusters were derived, assessed through the interviews, and a research agenda is proposed.

Understanding of the state-of-the art and highlight research opportunities.

Sources: ACM, 2012, Waller and Fawcett, 2013, Mayring, 2014, Souza, 2014, Nowosel et al., 2015, Gunasekaran et al., 2017, Nguyen et al., 2017, Vollmer et al., 2018.

Study II literature review, application, and future research

Other reviews and gaps

<table>
<tr><th colspan="2" rowspan="2">Classification</th><th colspan="6">SCOR framework</th><th rowspan="5">Other</th></tr>
<tr><th>Plan</th><th>Source</th><th>Make</th><th colspan="2">Deliver / Return</th><th>Enable</th></tr>
<tr><td rowspan="3">CCS framework (Note: Most other reviews in supply chain literature use the broad terminology of big data analytics)</td><td rowspan="2">AI/ ML methods</td><td></td><td>[Application focus] Strategic, tactical and operational of procurement: Spreitzenbarth et al., 2021 and [impact focus] Guida et al., 2021 and Allal-Chérif et al., 2021</td><td>For instance Li et al., 2017</td><td colspan="2">For instance Woschank et al., 2020</td><td></td></tr>
<tr><td colspan="6">For instance Min, 2010, Kobbacy and Vadera, 2011, The Economist, 2019, Brintrup, 2021</td></tr>
<tr><td>Others e.g. RPA</td><td colspan="6">For instance Waller and Facett, 2013, Hazen et al., 2014, Schoenherr and Speier-Pero, 2015, Souza, 2017, Gunasekaran et al., 2014, Nguyen et al., 2017, Choi et al., 2018</td></tr>
<tr><td colspan="9">Other</td></tr>
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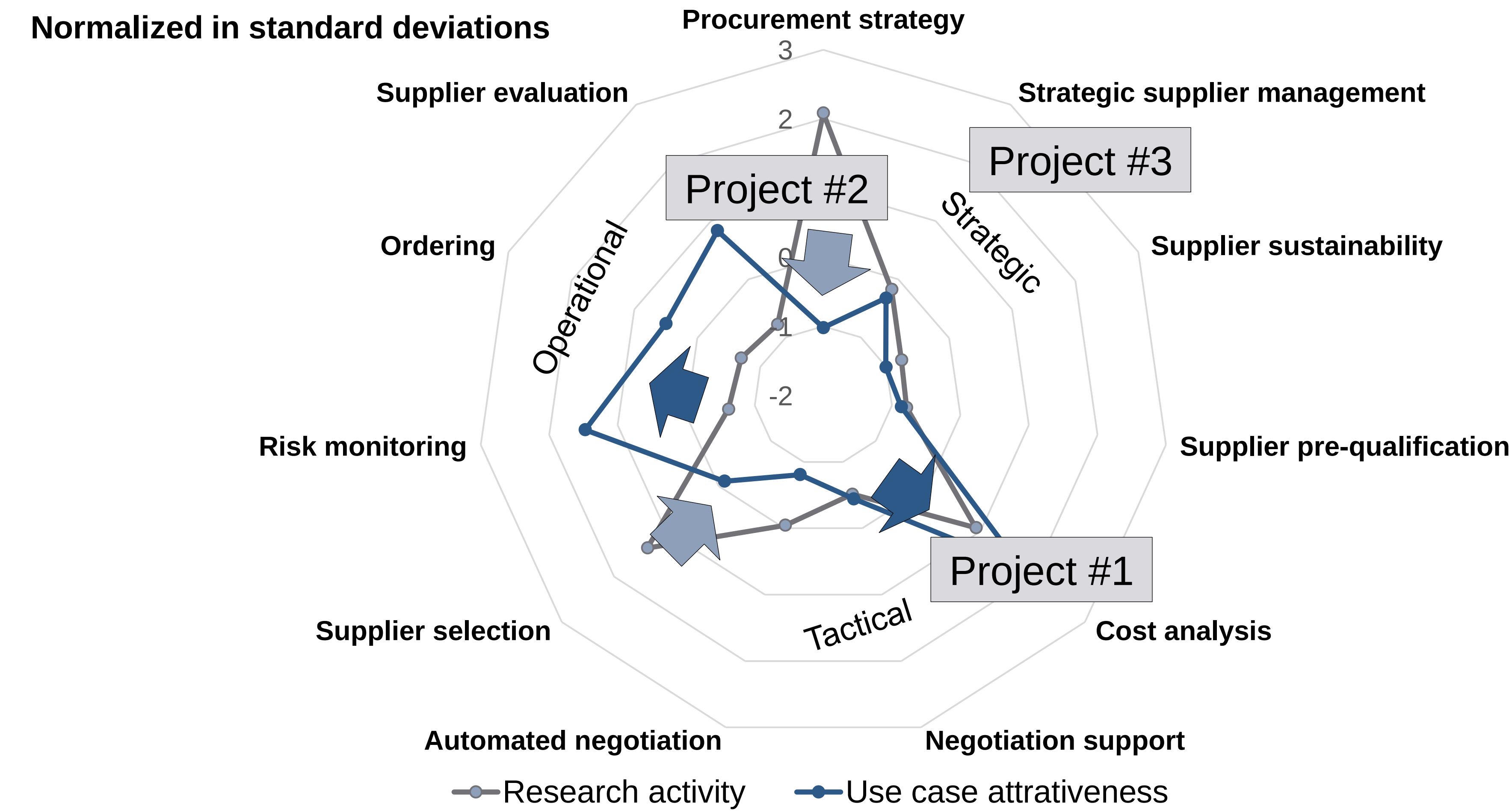
This work contributes to the understanding of AI and ML in operations management from theory and practical insights providing further research directions and provides an overview to supply managers looking for guidance. ACM frameworks offer a clear terminology as de-facto standard in information technology providing stronger clarity.

The methodology with SCOR and ACM can be applied in other reviews.

Sources: ACM, 2012, APICS Supply Chain Council, 2017.

Study II comparison of research activity and attractiveness

There is mismatch but also alignment



Focus on cost analysis and operational use cases.

Source: Spreitzenbarth et al., 2021a.

Study II extension the state of AI procurement vs sales

Potential academic master thesis is cooperation with Mannheim marketing chair

Research question: Why is procurement lagging in AI adoption versus sales?

Dimension	Procurement		Sales	
	Decisions	Data	Decisions	Data
Strategic	Value network	Overall costs and quality	Value proposition	Overall profits and revenue
Tactical	Supplier selection	Achieved Savings	Project bidding	Achieved projects
Operational	Supplier evaluation	Performance measurement	Project control	Performance measurement

→Building on the review of AI and ML in procurement presented at the IPSERA 2021, conduct comparative study, interesting master thesis topic. Consider strategic goals, potentially another MT focusing on the cross-functional potential of AI use cases ☺

Provide ideas and suggestions on how procurement could speed up.

Source: Spreitzenbarth et al., 2021b.

Study III overview of how to solve the sizing problem

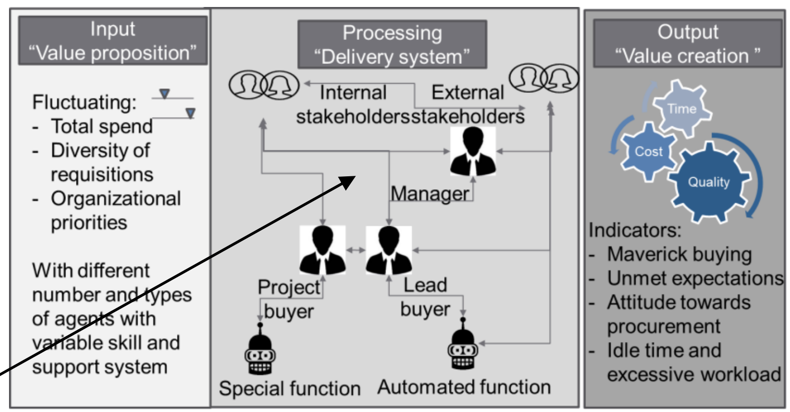
Optimize value creation of procurement through simulation as a work system

Research question: How to optimize procurement value creation through simulation?

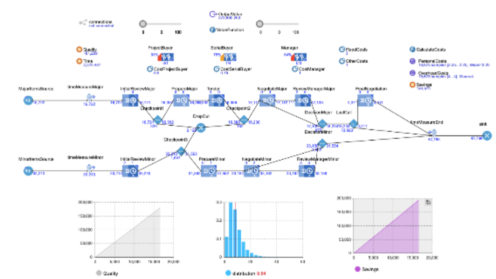
Preposition I: The sizing problem can be solved by optimizing the value function
Preposition II: Simulation shows flexibility value, e.g., through lean and agile principles

Dynamic system with feedback loops

Theoretical background



Results of case study



Real data to model and train the agents

Simulation as research method

Interesting opportunity for a technical and business oriented master thesis ☺

Design a prototype of a simulation-based procurement workflow system.

Sources: Spreitzenbarth, 2021, Spreitzenbarth et al., 2021c.

Summary with questions for discussion

Looking forward to your feedback

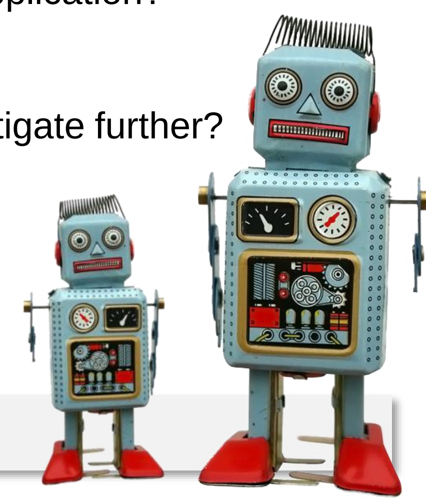
Summary of the three Ph.D. projects

- **#1 Case study:** Improve TCO prediction and understanding
- **#2 Review+:** Describe status quo and highlight the potential
- **#3 Model:** Solve organizational sizing with digital twin simulation

Questions for discussion

?

- **Value:** Where do you see the most value for future research and practical application? What do you suggest to focus on in the design of the Ph.D.?
- **Novelty:** Which relevant works and theories would you recommend to investigate further?
- **Method:** Where do you see shortcomings? What would you do differently?



Looking forward to an interesting discussion!

Thanks for your time! The references are summarized below.

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