A meta-analysis of industry 4.0-related technologies that are suitable for lean manufacturing

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A META-ANALYSIS OF INDUSTRY 4.0-RELATED TECHNOLOGIES THAT ARE SUITABLE FOR LEAN MANUFACTURING

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AGENDA

*The present work proposes a meta-analysis of **Lean Production** and **Industry 4.0** Key Enabling Technologies*

The CONTEXT: the evolution of manufacturing

The meta-analysis

The Key Enabling Technologies

- *Reliability of Technologies and Methodologies in operation*
- *Technology Deployment*

Conclusion & Future Outlooks

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THE EVOLUTION OF MANUFACTURING

- Lean and Industry 4.0 (I4.0) are key topics in manufacturing

➢ Lean is a well-recognised and successful business strategy that has proven its merits since Taichi Ohno formalized the Toyota Production System (1)

3rd Industrial Revolution

➢ Industry 4.0 can be defined as the integration of complex machineries and devices with networked sensors and software to predict, control and plan the manufacturing of the future (2)

4th industrial revolution

(1) OHNO, Taiichi. *Toyota production system: beyond large-scale production*. crc Press, 1988

(2) see KAGERMANN, Henning, et al. *Recommendations for implementing the strategic initiative INDUSTRIE 4.0: Securing the future of German manufacturing industry; final report of the Industrie 4.0 Working Group*. Forschungsunion, 2013

Both pictures retrieved from the web at https://it.wikipedia.org/wiki/Industria_4.0 (accessed 07/09/2019)

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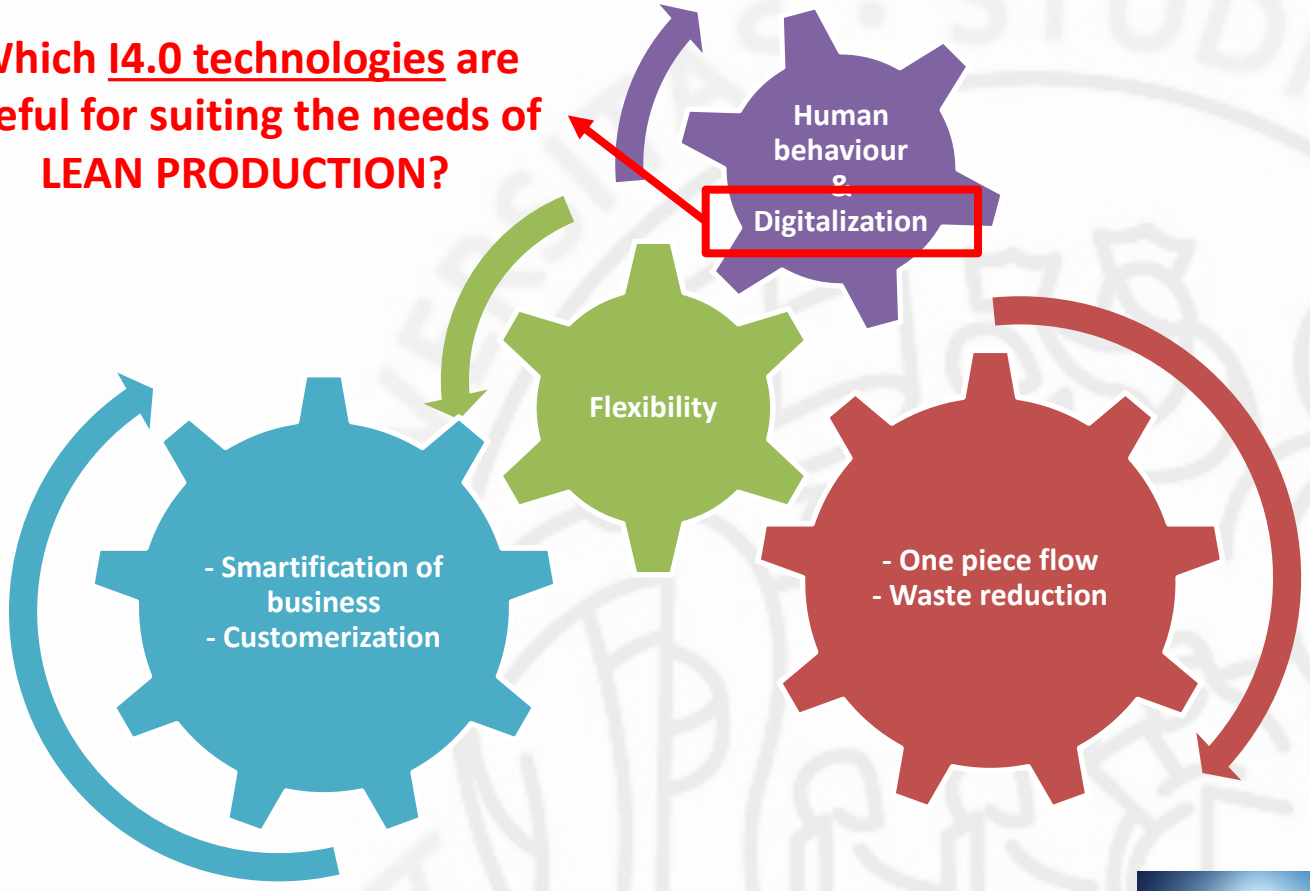
THE EVOLUTION OF MANUFACTURING

- Lean and Industry 4.0 (I4.0) are key topics in manufacturing

Which I4.0 technologies are useful for suiting the needs of LEAN PRODUCTION?



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- **Source:** Scopus, www.scopus.com (visited on November, 2018)
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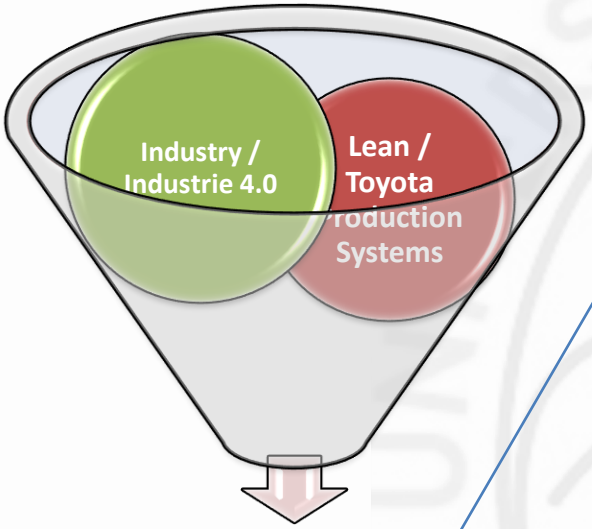

951 results

- n. 61 "direct" results: seed 1
- n. 854 "cited" documents: seed 0

376 results

- n. 51 "direct" results: seed 1
- n. 325 "cited" documents: seed 0

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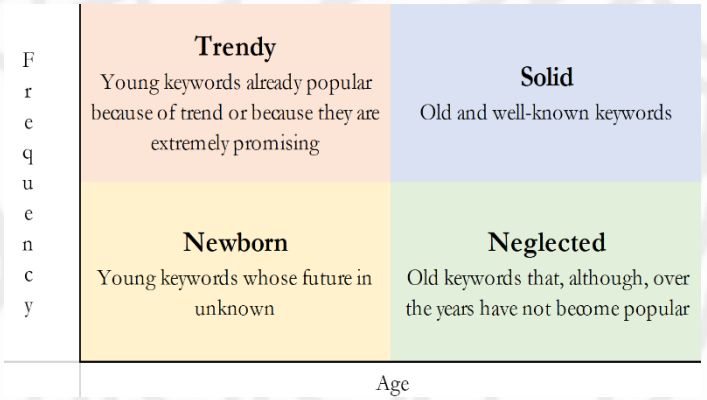
- **Methods:** Keyword-based analysis by Fadlalla, A. and Amani, F. (2015) 'A keyword-based organizing framework for ERP intellectual contributions', Journal of Enterprise Information Management, 28(5), 637-657
  - **Tools:** Weak clustering co-word algorithm by Coulter, N., Monarch, I. and Konda, S. (1998) 'Software Engineering as Seen through Its Research Literature : A Study in Co-Word Analysis', Journal of the Association for Information Science and Technology, 49(1997), pp. 1206–1223



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KEYWORD-BASED ANALYSIS

- **Seed 1:** the table seems more dominated by propositions and their evolution over time, e.g. cyber physical systems; IoT; I4.0; internet of things; just in time; lean production → specific application in I4.0

cyber physical production systems; digital lean manufacturing; digitization; literature review; manufacturing industry; model.	**cyber physical systems; iot; industrie 4.0; industry 4.0; internet of things; just in time**; lean automation; **lean management; lean manufacturing**; lean product development; **lean production**; lean production systems; learning factory; production; **production management**; simulation game; smart manufacturing; supply chain; **supply chain management; toyota production system**.
agile manufacturing; **agile production**; apparel industry; **artificial neural networks; big data**; bps; business experiments; capabilities development trajectory; competency; **customized production**; digital lean enterprise; **digital manufacturing**; digital shop floor management; digital transformation; **digital waste; effects of digitalization**; enterprise architecture; enterprise performance; enterprise resourse planning (erp); firm choices; framework industrie 4.0; furniture industry; future research avenues; glenday sieve; **human resource development**; human resource management; improvement cycle; industrial internet; industry development; industry transformation; innovation practice; **key performance indicator (kpi)**; kpi; management; manufacturing execution system (mes); material traceability; **maturity index**; **maturity models**; medium enterprise (sme); multiple case method.; organisation strategy; pms; process control; product lifecycle; production efficiency; production planning system; production process; production systems; **radio frequency identification**; **rami**; readiness index; reference models; simulation modeling; small; status quo; survey; sustainability; sustainable value stream mapping; talent management; talent need; **value stream; value stream management; value stream mapping; waste.**	abc; **accounting for lean**; blue collar; **capacity management**; collaborative engineering; connected industry; control loop; cost models; crm; **eco efficiency**; efficiency assessment; emerging economies; empirical research; engineer to order; engineering management; global supply chain management; h2020 spire; idle capacity; industrial symbiosis; industry 4; industry 4 0; industry 40; information and communication technologies; integration; intelligent manufacturing; intelligent production logistics; **intra logistics**; jidoka; **layout planning**; lean and smart manufacturing; lean intelligent manufacturing model; lean six sigma; logistics model; manufacturing management; material flow technology; modular logistics; operational efficiency; pharmaceutical; predictive maintenance; process industries; process industry; process optimization; quality management system; remanufacturing; **risk based maintenance**; shopfloor management; small and medium sized enterprises; smart engineering; smart maintenance; smart product development; supply chain model; survey analysis; sustainable manufacturing; systems; tdabc; technology management; urban rail vehicle assembly; vocational education and training; worker participation.

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KEYWORD-BASED ANALYSIS

- **Seed 0:** the table seems to give more space to the 'practical' tools concerned with the above-mentioned propositions, e.g. advanced manufacturing; artificial intelligence; augmented reality; big data analytics; collaborative automation; condition-based maintenance and so on → specific tools

advanced manufacturing; **artificial intelligence**; **augmented reality**; big data; **big data analytics**; **collaborative automation**; cyber physical production systems; demand forecasting; **digital twin**; digitalization; digitization; **distributed systems**; eco industrial park; energy efficiency; engineer to order; industrial ecology; **industrial internet**; information sharing; **intelligent manufacturing**; postural analysis; **predictive maintenance**; rfid technology; smart manufacturing; waste; …	**condition based maintenance**; cyber physical system; fuzzy logic; ict; internet of things; just in time; **kanban; kanban system**; lean engineering; lean manufacturing; lean production; lean thinking; meta-analysis; multi agent system; project management; simulation; six sigma; sme; **statistical process control**; **traceability**; **visual management**; …
3d sensors; **4d printing**; **action-based learning**; **additive manufacturing**; **artificial neural networks; big data visualization**; **bottleneck detection**; cloud gateway; computer graphics; **conwip**; cpps; crm; **cyber physical manufacturing systems; data flow**; **data mining**; **dynamic flow shop**; **dynamic resource allocation; …**	best practice; chinese manufacturing; comparison; **contingency research**; contingency theory; customer and supplier relationships; **cutting-stock**; **demand information sharing**; diagnostics; digital factory; discrete simulation; empirical investigation; enterprise software; **error prevention**; execution system; extended lean enterprise; flow shop; global; **hmi**; innovativeness; **insertations**; internet-of-things; inventory; lean; **longitudinal analysis**; lot-sizing; manufacturing industry; measurement/methodology; **media coverage**; media; modularity; non-repetitive production; order picking; parameters; **pick-by-vision**; picking error; production control; prognostics; promotion investments; research criticism; research evaluation; research integration; research methodology; research methods; research synthesis; robust optimization; sensor data fusion; signal processing; simulation; structural equation modelling; survey research; total quality management; war for talent; wireless network; wood sector; workload control …

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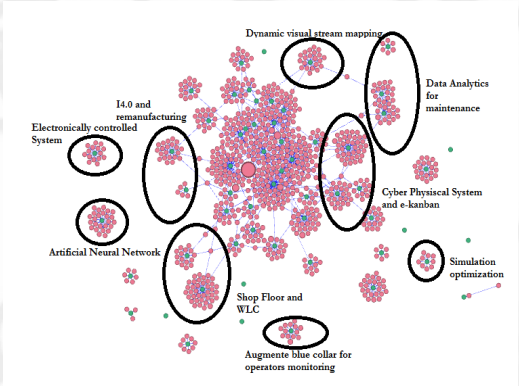
- **Methods:** Research Network analysis by Jacomy et *al.* (2014) 'ForceAtlas2, a continuous graph layout algorithm for handy network visualization designed for the Gephi software', PloS one, 9(6), e98679.
  - **Tools:** co-citation algorithm by Jacomy et *al.* (2014) for a specific Science Mapping (implemented in Gephi 0.9.2)



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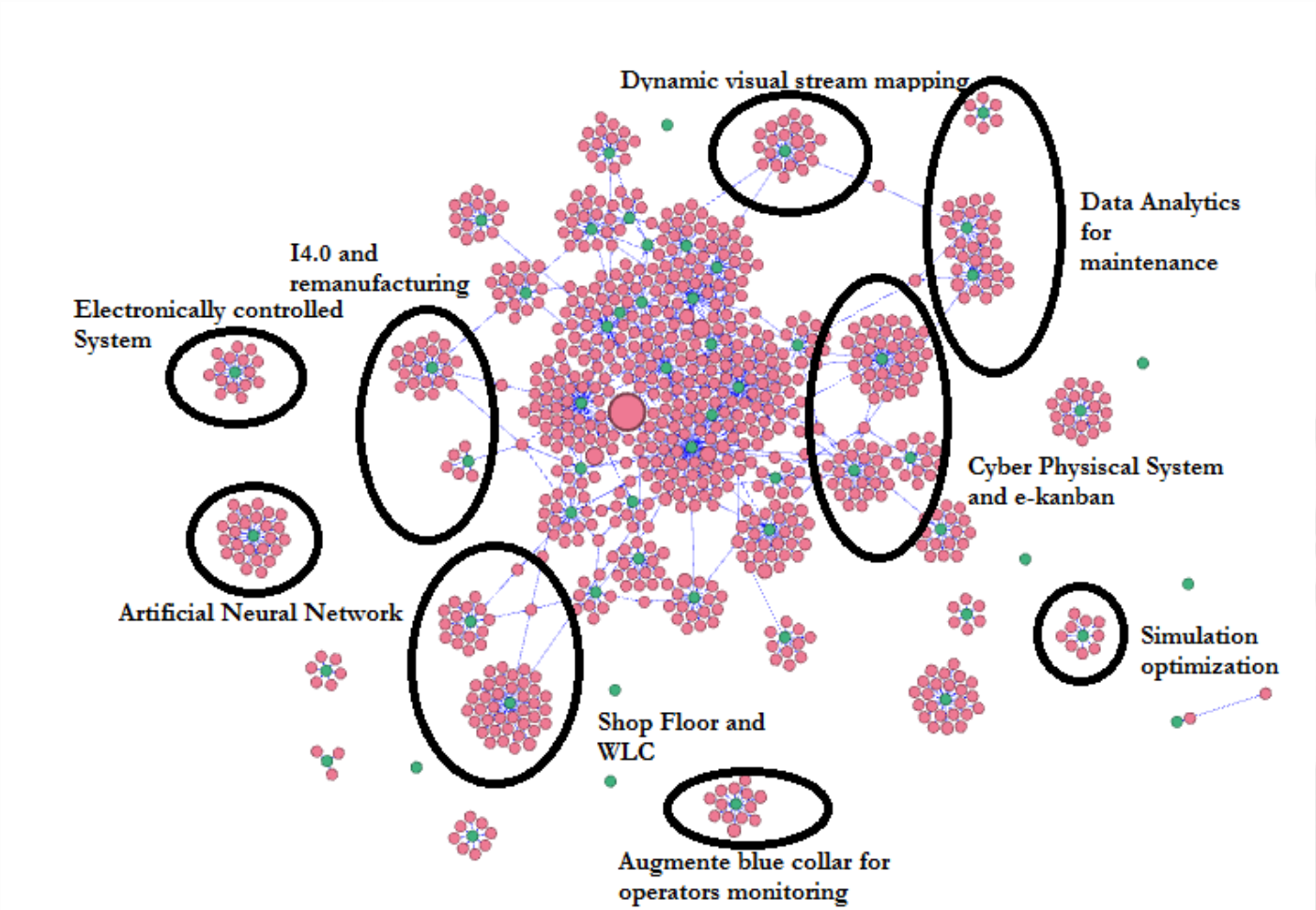
SCIENCE MAPPING



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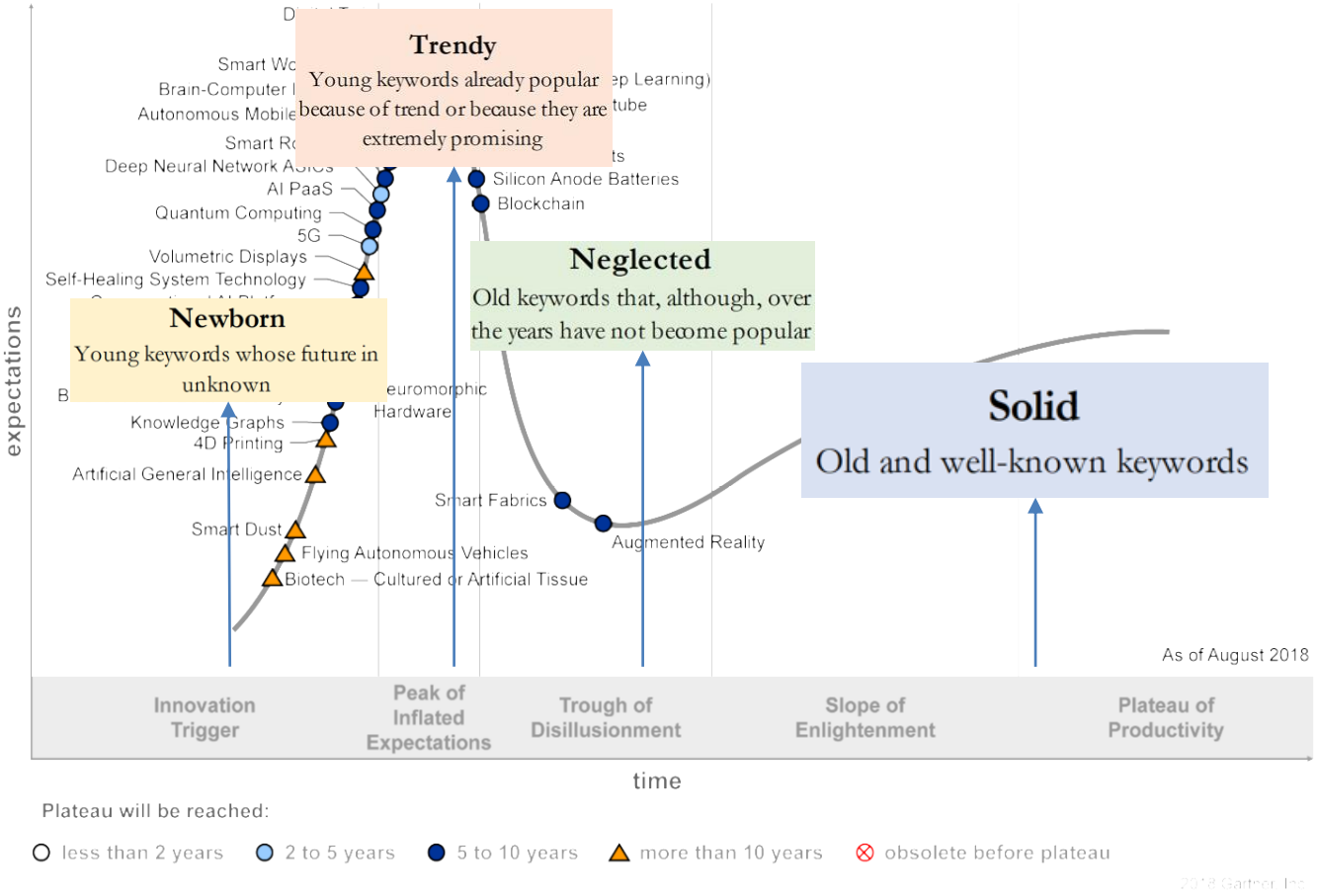
RELIABILITY OF TECHNOLOGIES AND METHODOLOGIES IN OPERATION

Hype Cycle Models are useful to "measure" the current development of technologies. The most important and used **Technology Hype Cycle** is the **Gartner® Hype Cycle**



Source of the Gartner curve:
Gartner, Hype Cycle for Emerging Technologies, 2018, Mike Walker, 6 August 2018

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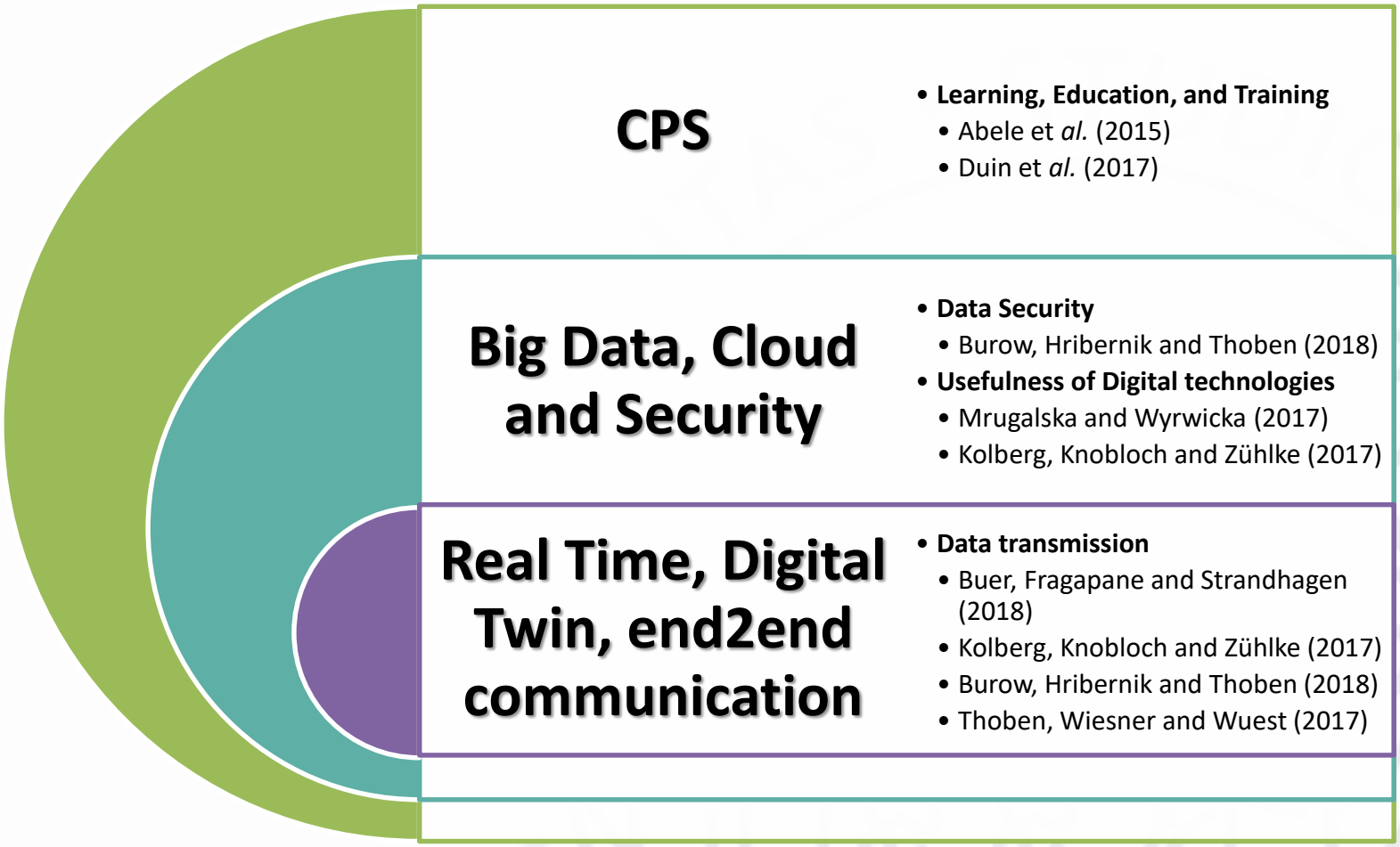
TECHNOLOGY DEPLOYMENT



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TECHNOLOGY DEPLOYMENT

	iBin	e-Kanban	Digital twin	Deep learning	Virtual Assistants	Augmented/ mixed reality	RFID	Big data	Information sharing	Cyber physical system	End-To-End communication
Bertolini et al. 2018			X				X		X	X	
Khalid et al. 2018			X		X	X				X	X
Burow et al. 2018								X	X		X
Duin et al. 2017			X			X				X	
Kolberg et al. 2017	X				X	X	X		X		X
Abele et al. 2015			X		X	X				X	
Mrugalska & Wyrwicka 2017	X	X			X		X	X	X		
Buer et al. 2018	X	X					X				X
Thoben et al. 2017				X		X			X	X	X

Marra, M., Di Biccari, C., Lazoi, M. and Corallo, A. (2018) 'A Gap Analysis Methodology for Product Lifecycle Management Assessment', *IEEE Transactions on Engineering Management*. 65(1), 155-167

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CONCLUSION AND FUTURE OUTLOOKS

- The most common implementation of I4.0 into Lean environment involve:
  - CPS
  - end-to-end communication
  - information sharing
  - augmented & mixed reality
  - virtual assistants
  - RFID
  - Digital Twins
- No performance-benefits analysis

FUTURE WORKS are supposed to deal with:

- implementation of proposed systems into study cases, both real and simulated
- analysis of performance

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References used in the Technology Deployment section

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