Determinants of an appropriate degree of autonomy in a Cyber-Physical Production System

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Anwendungszentrum
INDUSTRIE 4.0

Agenda

- What is autonomy?
- How autonomy can be measured?
- What is the right degree of autonomy?
- How do we test our approaches?
- Further research

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What is autonomy?

- Freedom to act independently
- Capacity to make an informed, uncoerced decision
- Capacity of a system to make a decision about its activities without the involvement of another system or operator

➡ A production system is autonomous, when it is capable to make a decision about its activities without the involvement of another system or operator

When is autonomy advantageous?

New technologies	Kreimeier 2013
Challenging customer requirements	Gudszend 2002
Variable lot sizes	Kreimeier 2013
Higher degree of individualization and more dynamic markets	Meißner et at. 2013
Shorter ramp-up cycles	Heins et al. 2008
Frequent need for adaptation	Mersmann 2012

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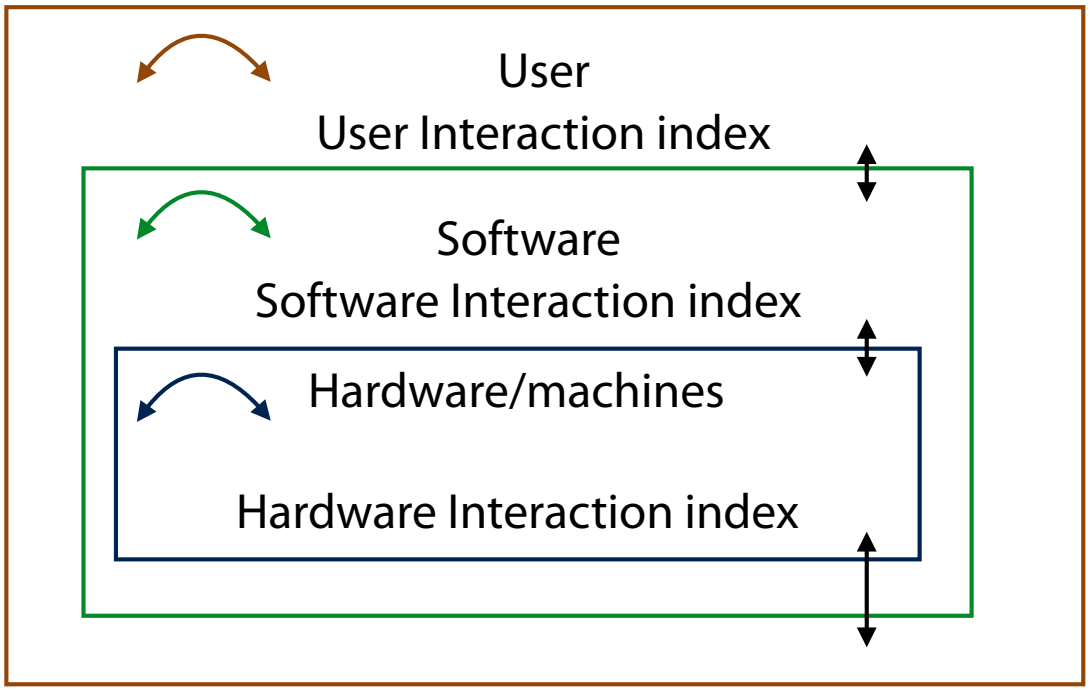
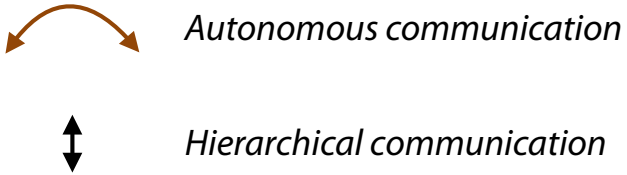
Autonomy index

Market-based approach

Measuring the autonomy index





$$\text{Autonomy Index AI} = \frac{DE_{aut}}{DE_{all}} = \frac{\sum_{z \in Z} \sum_{j=1}^{m} D_{zxj} + \sum_{i=1}^{n} D_{xxi}}{\left(\sum_{z \in Z} \sum_{j=1}^{m} D_{zxj} + \sum_{i=1}^{n} D_{xxi} \right) + \left(\sum_{z \in Z} \sum_{j=1}^{m} DN_{zxj} + \sum_{i=1}^{n} DN_{xxi} \right)}$$

Lass/Theuer/Gronau 2012

Communication of control center

3,152 INFO ToolAdapter:300 - Curve PowerConsumptionreceived configuration Inductor Coil from Workingstep Heating through induction

3,152 INFO ToolAdapter:300 - Curve Temperaturereceived configuration Inductor Coil from Workingstep Heating through induction

3,152 INFO ToolAdapter:300 - Curve Noisereceived **configuration** Inductor Coil from Workingstep Heating through induction

3,152 INFO ToolAdapter:300 - Curve Vibrationreceived configuration Inductor Coil from Workingstep Heating through induction

3,152 INFO ToolAdapter:300 - Curve Noisereceived configuration Inductor Coil from Workingstep Clinch

3,152 INFO ToolAdapter:300 - Curve Temperaturereceived configuration Inductor Coil from Workingstep Clinch

3,154 INFO ToolAdapter:284 - Curve **Material Verschleissreceived** tool Schleifwerkzeug from Workingstep Schleifen Grob

3,154 INFO ToolAdapter:300 - Curve Krnungsgradreceived configuration Schleifwerkzeug from Workingstep Schleifen Grob

3,155 INFO ToolAdapter:300 - Curve Leistungsaufnahmereceived configuration Schleifwerkzeug from Workingstep Schleifen Grob

3,155 INFO ToolAdapter:284 - Curve Oelspritzer Verschleissreceived tool Oelspritzer from Workingstep Schleifen Fein

3,155 INFO ToolAdapter:300 - Curve Spritzdruckreceived configuration Oelspritzer from Workingstep Schleifen Fein

3,155 INFO ToolAdapter:300 - Curve Leistungsaufnahmereceived configuration Oelspritzer from Workingstep Schleifen Fein

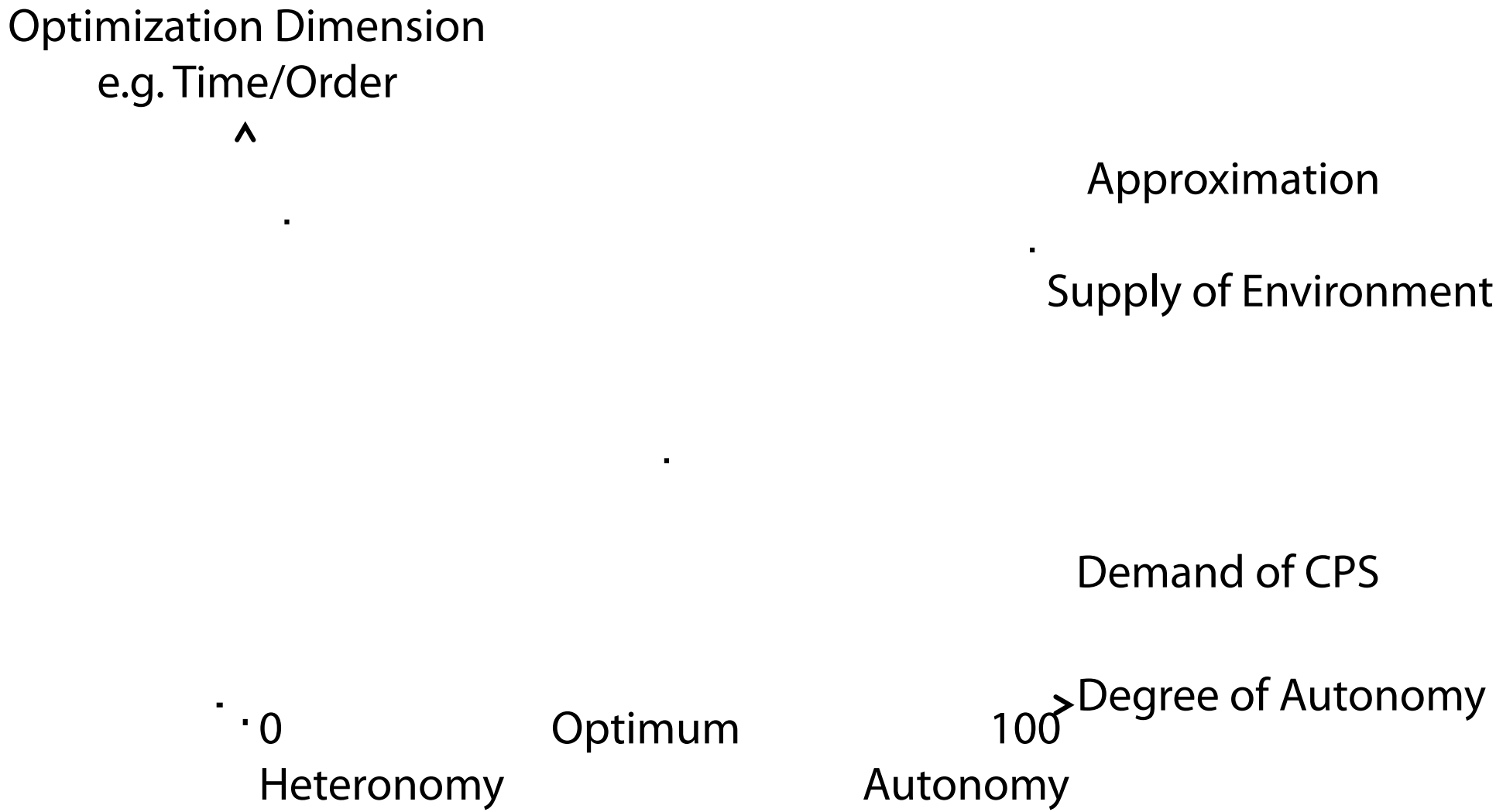
3,155 INFO ToolHandler:247 - Content Curve Oelbehaelter von Maschine CNC Frse + Schleifer + Polierer wurde hinzugefgt

3,157 INFO ADSFunctions:223 - PLCVar value: 0

3,157 INFO ToolAdapter:284 - Curve Material Verschleissreceived tool Schleifwerkzeug from Workingstep Schleifen Grob

3,158 INFO ToolAdapter:300 - Curve Krnungsgradreceived configuration Schleifwerkzeug from Workingstep Schleifen Grob

Market-based approach



Gronau/Bender/Grum 2016

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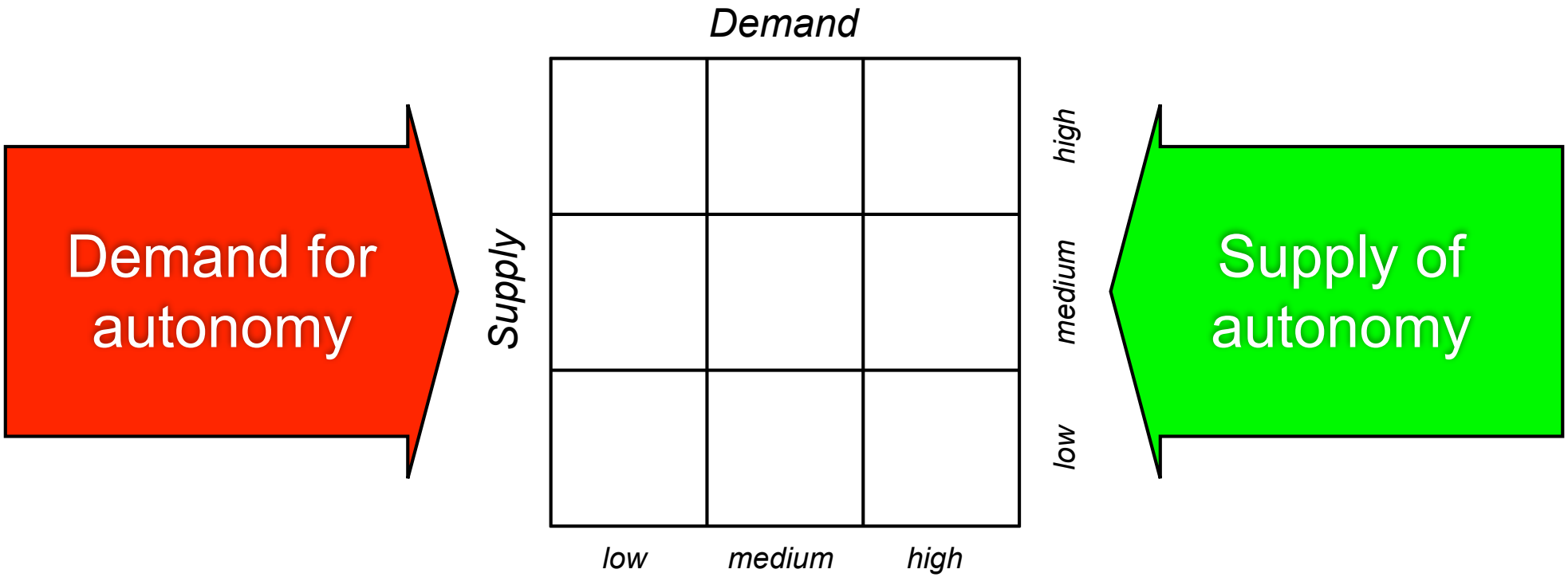
Demand and supply of autonomy



Characteristics of a production system

Product range	Specification by customer	Serial products with customer-specific variations	Standard products with variations	Standard products without variations
Product structure	One-piece-product	Multiple-piece-products with simple structure	Multiple-piece-products with complex structure	
Order trigger	Manufacturing on demand with single orders	Manufacturing on demand with blanket orders	Manufacturing on stock	
Disposition	Following the customer's order	Mainly following the customer's order	Mainly MRP-based	MRP-based
Demand planning	No relevant external supply	Relevant external supply	Huge external supply	
Manufacturing process	Unique manufacturing	Unique and small lot manufacturing	Serial manu-facturing	Mass manu-facturing
Manufacturing organization	Construction site	Shop floor	Group-/ line assembly	Line production
Share of self-manufactured parts	Low	Medium	High	

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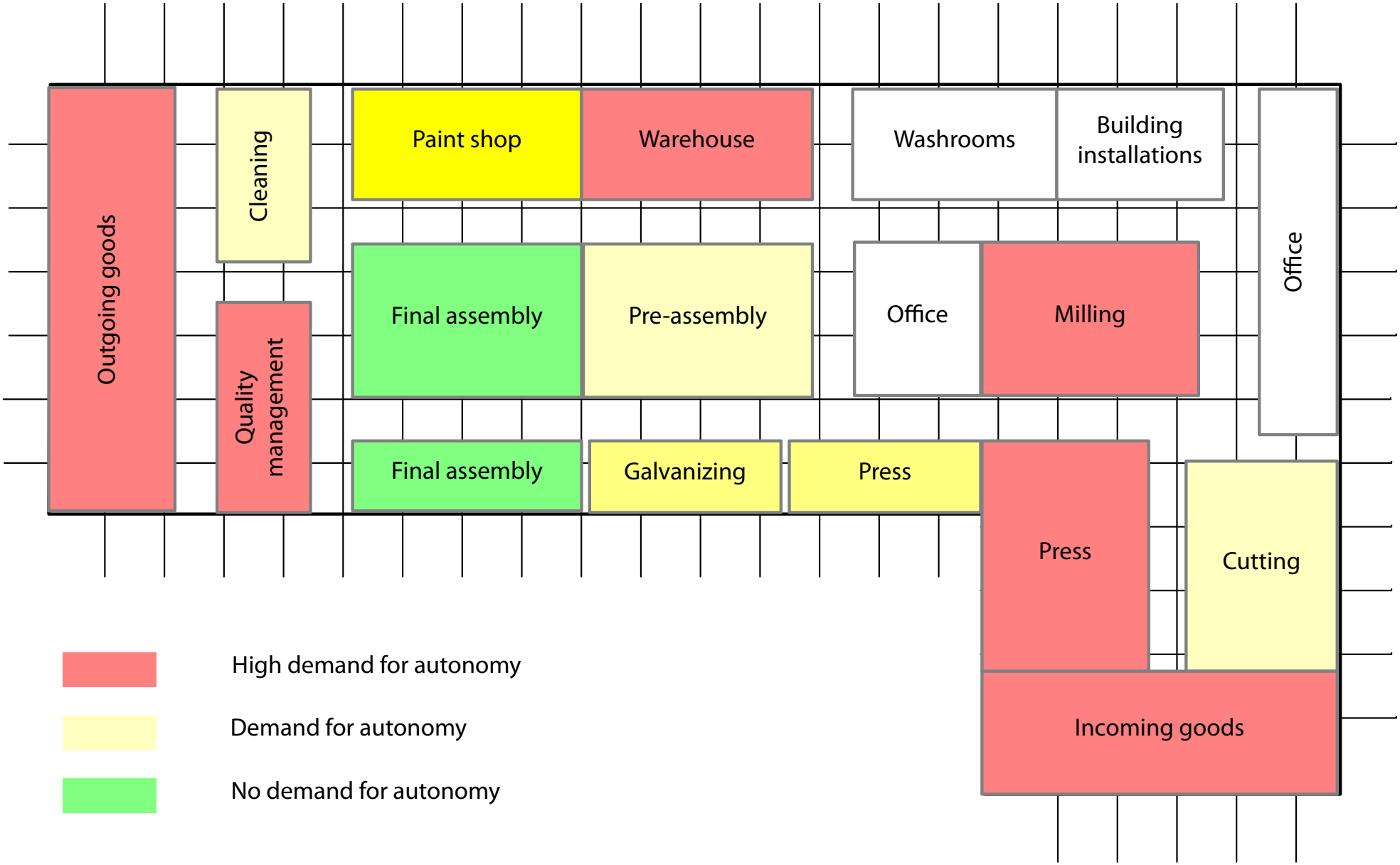
Example: Production of artificial knee joints

Attribute	Attribute values				Actual	Max
Product range	Specification by customer	Serial products with customer-specific variations	Standard products with variations	Standard products without variations		
Need for autonomy	++	+	o	-	0,33	1
Product structure	One-piece-product	Multiple-piece-products with simple structure	Multiple-piece-products with complex structure			
Need for autonomy	-	o	+		0,33	1
Order trigger	Manufacturing on demand with single orders	Manufacturing on demand with blanket orders	Manufacturing on stock			
Need for autonomy	++	+	o		0,66	1
Disposition	Following the customer's order	Mainly following the customer's order	Mainly MRP-based	MRP-based		
Need for autonomy	++	+	o	-	0,33	1
Demand planning	No relevant external supply	Relevant external supply	Huge external supply			
Need for autonomy	o	+	++		0,66	1
Manufacturing process	Unique manufacturing	Unique and small lot manufacturing	Serial manufacturing	Mass manufacturing		
Need for autonomy	++	+	o	-	0,33	1
Manufacturing organization	Construction site	Shop floor	Group-/ line assembly	Line production		
Need for autonomy	+	++	+	-	0,66	1
Share of self-manufactured parts	Low	Medium	High			
Need for autonomy	o	+	++		0,66	1
					3,96	8
				Autonomy demand	**49,5 %**	

Example of an „autonomy heat map“



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Modelling of fixed elements (e.g. machines)

Cockpit

Modeling only of the *relevant* properties

CPS

Communication

Modelling of movable elements (e.g. workpieces)

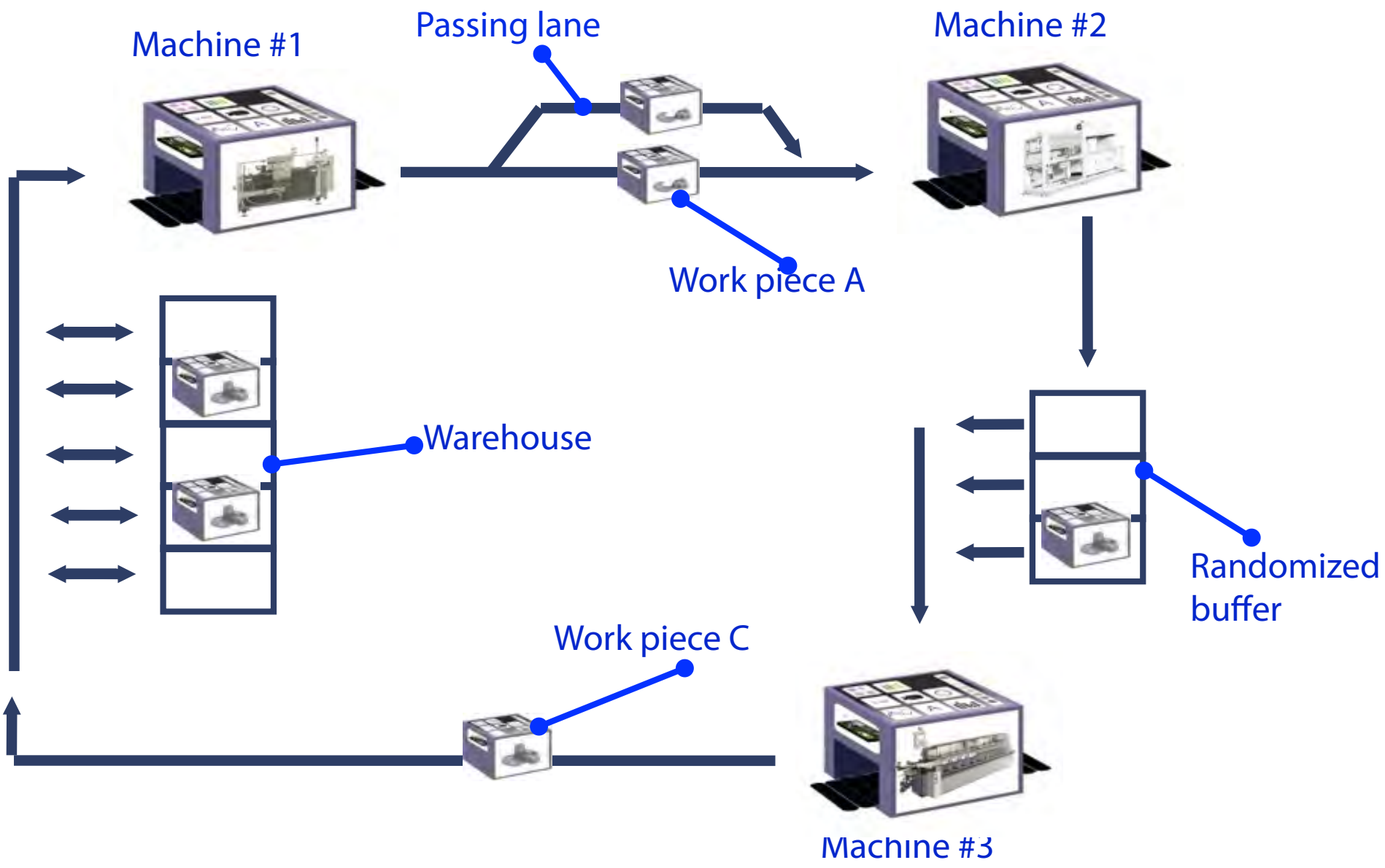
Cockpit

Modeling only of the *relevant* properties

CPS

Communication

Manfacturing and logistics processes in a factory




www.industrie40-live.de
Part 4711 is missing
I need resupply!
Disturbance cleared in 50 min
New order: 50 pieces till Monday

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Ongoing research

- How can we improve the adaptability of **existing** logistical and manufacturing processes?
- How do we mix human's and machine's autonomy?
- How can we improve the human-machine interface?

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