INDUSTRY 5.0
LEAN DESIGN AND DIGITALISATION

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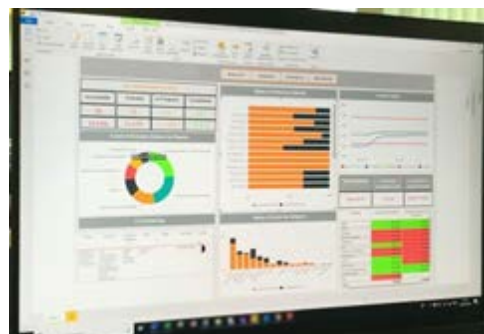University of HUDDERSFIELD
Inspiring global professionals

Arts and Humanities

IDL

https://research.hud.ac.uk/institutes-centres/idl/
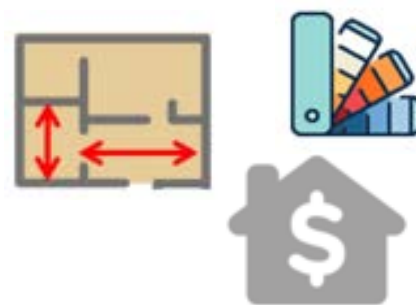
DIGITAL TECHNOLOGIES
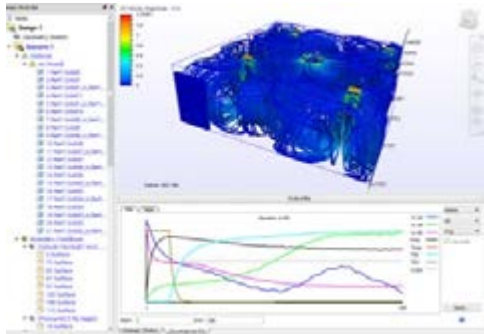
ENERGY EFFICIENCY

SERIOUS GAMES
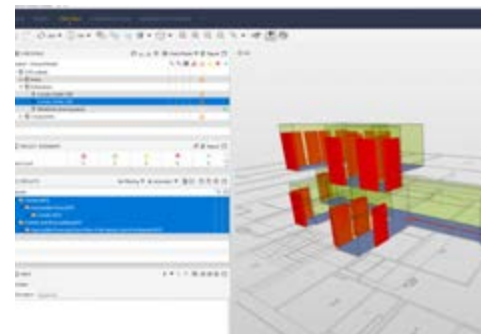
AUTOMATED COMPLIANCE

UNMANNED AERIAL VEHICLES

ARTIFICIAL INTELLIGENCE
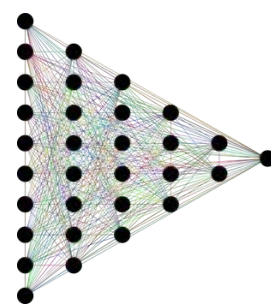
MACHINE LEARNING
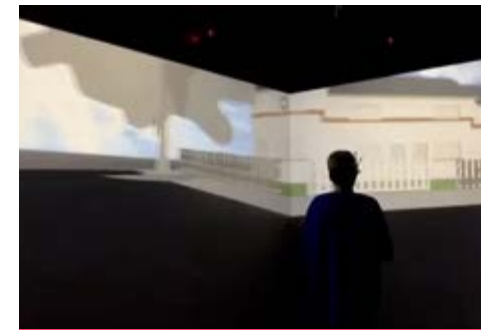
VIRTUAL REALITY
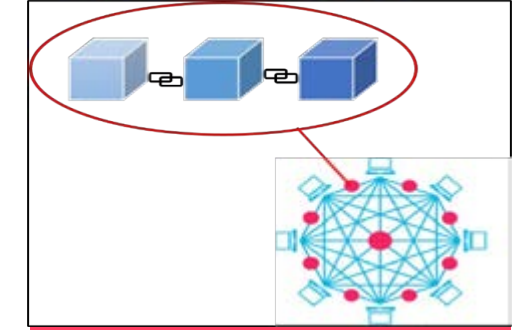
BLOCKCHAIN

HEALTHCARE DESIGN
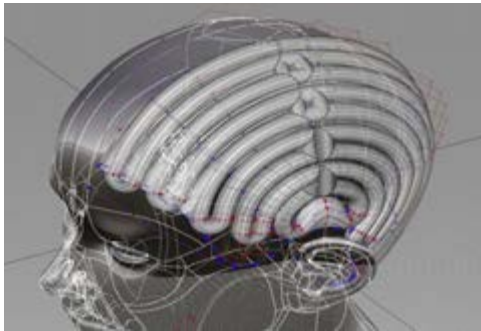
HEALTHCARE PRODUCTS

HEALTHCARE BUILT ENVIRONMENT

USER EXPERIENCE

PARTICIPATORY DESIGN
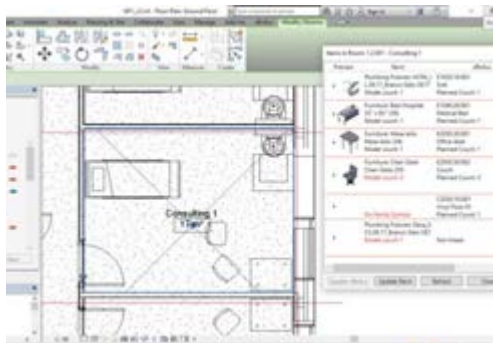
REQUIREMENTS MODELLING

HEALING BUILT ENVIRONMENT

EVIDENCE BASED DESIGN

VALUE

HOW TO EXPLAIN LEAN?

- It is commonly known that lean is about reducing waste and increasing value, but beyond that, the explanation for lean has been lacking

- One big puzzle is this very concept of waste, not recognised by the mainstream literature on management

- Another big puzzle is the concept of value…

LEAN &
INDUSTRY 4.0 5.0

The Four Industrial Revolutions

Industry 1.0

Mechanization and the introduction of steam and water power

Industry 2.0

Mass production assembly lines using electrical power

Industry 3.0

Automated production, computers, IT-systems and robotics

Industry 4.0

The Smart Factory. Autonomous systems, IoT, machine learning
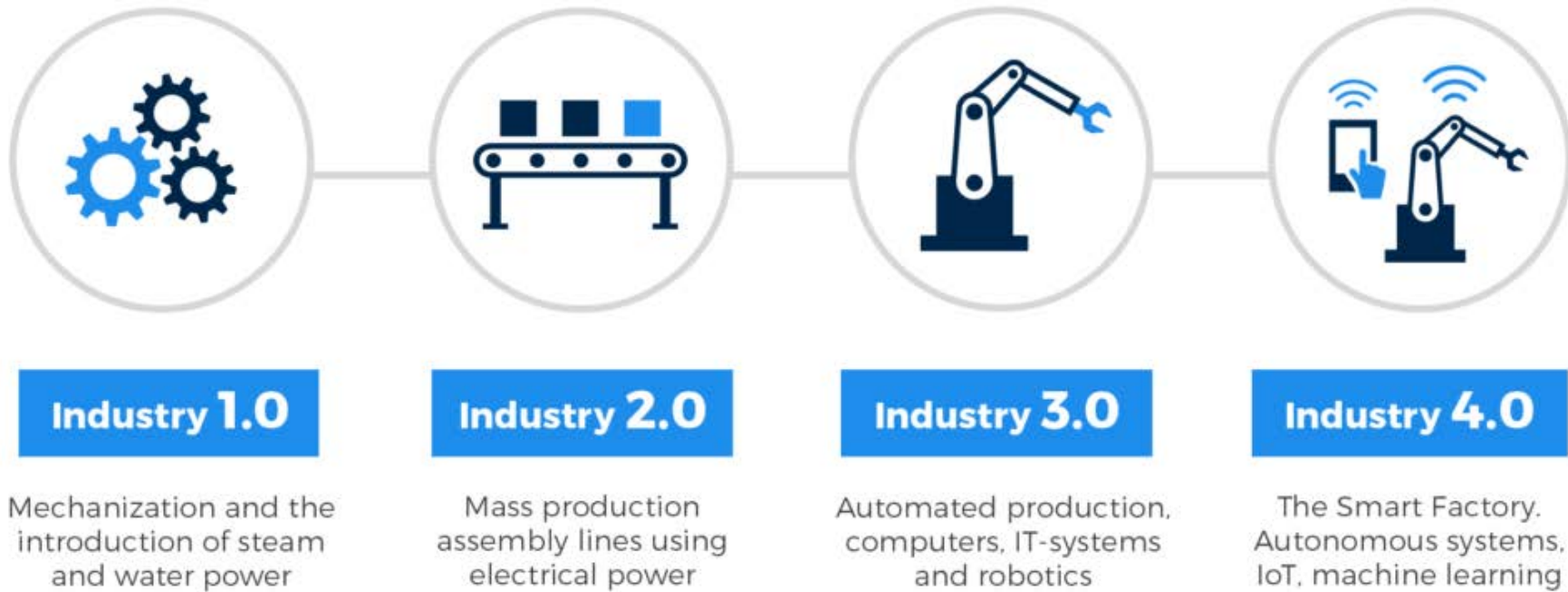
WHAT IS INDUSTRY 4.0?

- Publicly introduced at the Hannover fair - 2011

- In the Industry 4.0 era, production systems, in the form of Cyber Physical Production Systems

  - can make intelligent decisions through real-time communication and cooperation between "manufacturing things', enabling flexible production of high-quality personalised products at mass efficiency

TECHNOLOGY DRIVEN TRANSFORMATION

Focus on digitalisation and AI driven technologies

Towards efficiency and flexibility of production

Source: Xu at al.,2021 journal of Manufacturing Engineering

INDUSTRY 4.0 DESIGN PRINCIPLES

- Service oriented reference architecture

- Intelligent, self organising CPPS

- Interoperability between CPPS and humans

- Adaptability and flexibility to changing requirements

- Optimisation for overall equipment effectiveness

- Data integration across disciplines and the entire lifecycle

- Reliable and secured communications between businesses

- Data security

Industry 4.0 - Technological pillars

Cybersecurity

Cognitive Computing

Cloud Computing

RFID technologies

Mobile technologies

Internet of Things

Machine To Machine

Big Data/ Analytics

3D Printing

Advanced Robotics

4.0 Technology

Source: Saturno et. al. 2017

WHAT IS IoT?

IoT can be defined as intelligent artefacts
connected via the internet, where artefacts
exchange information with each other,
with their users, and with their database

(Wortman & Flüchter, 2015)
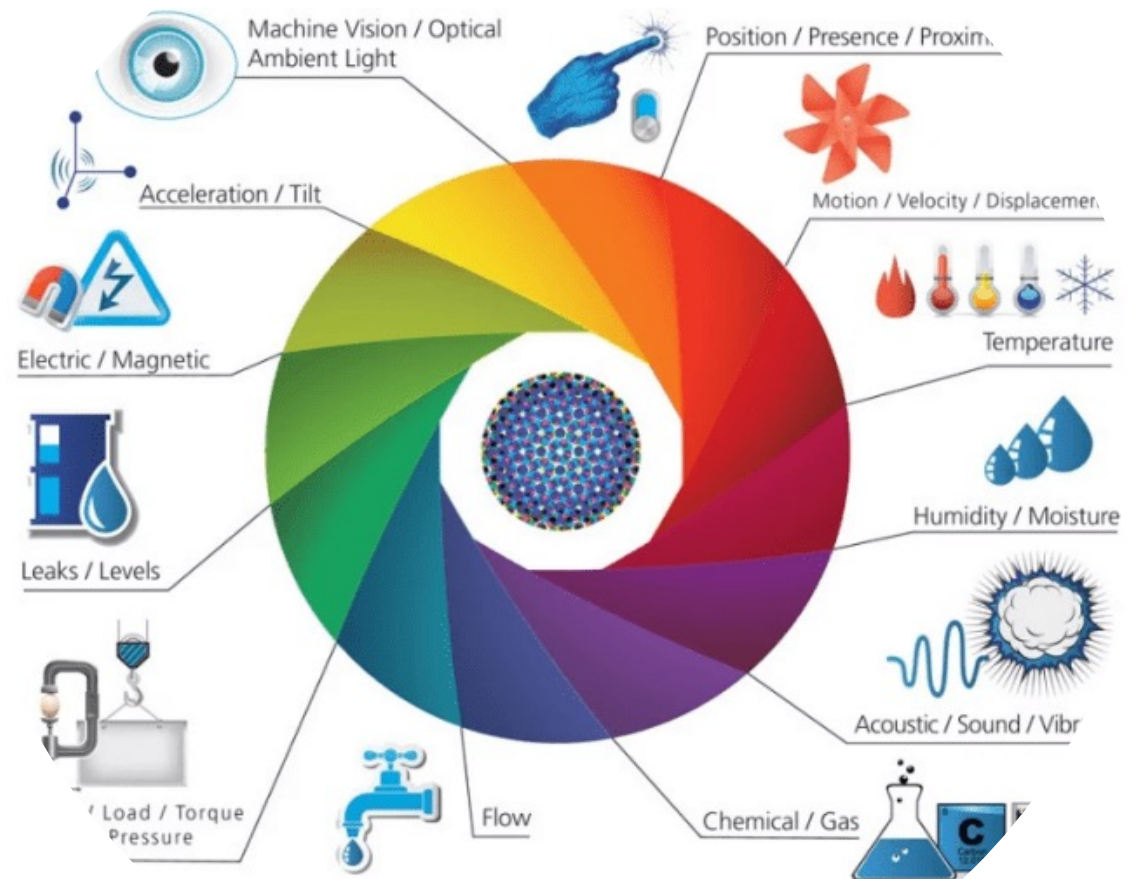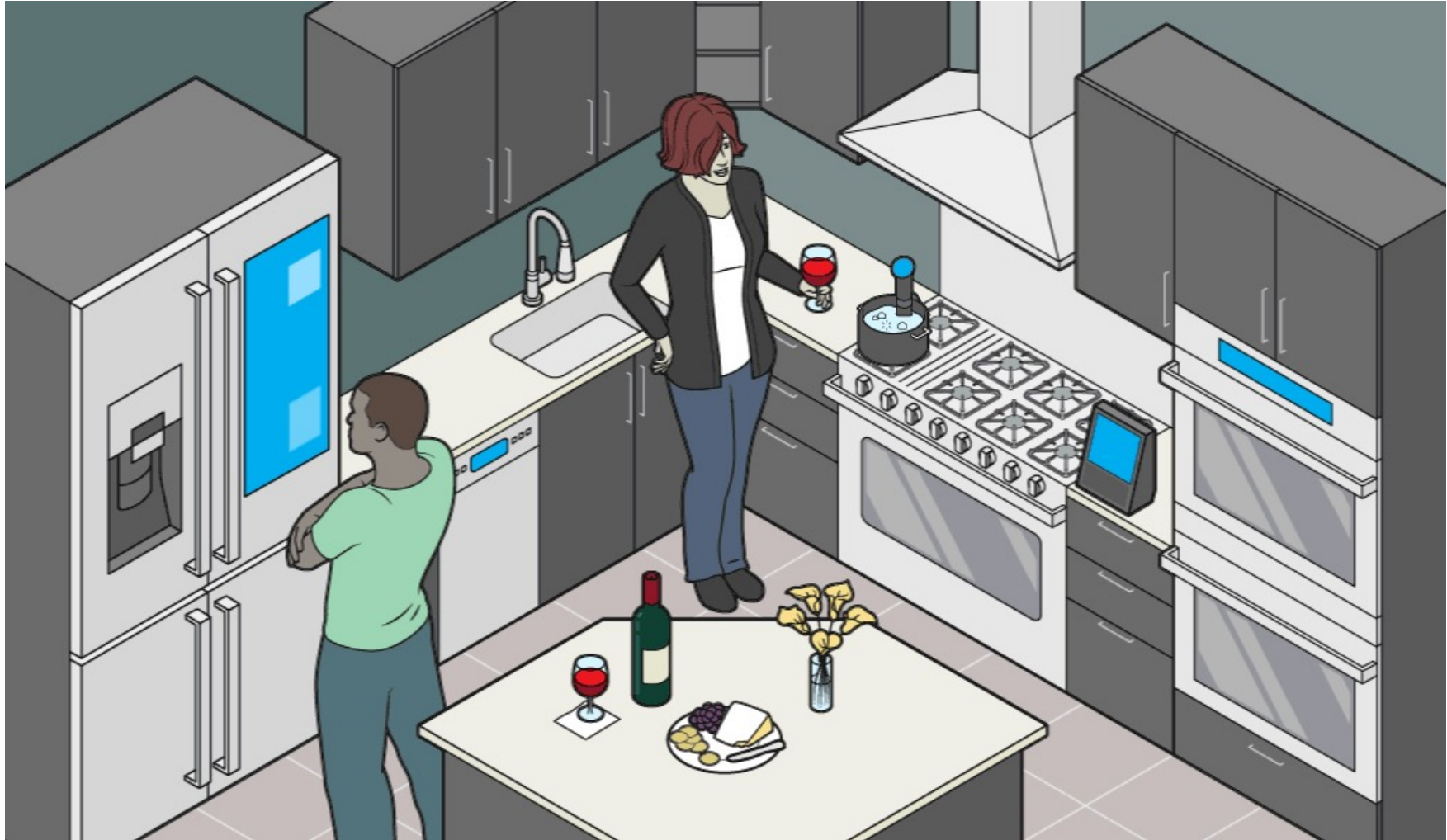
(V2COM, 2020)
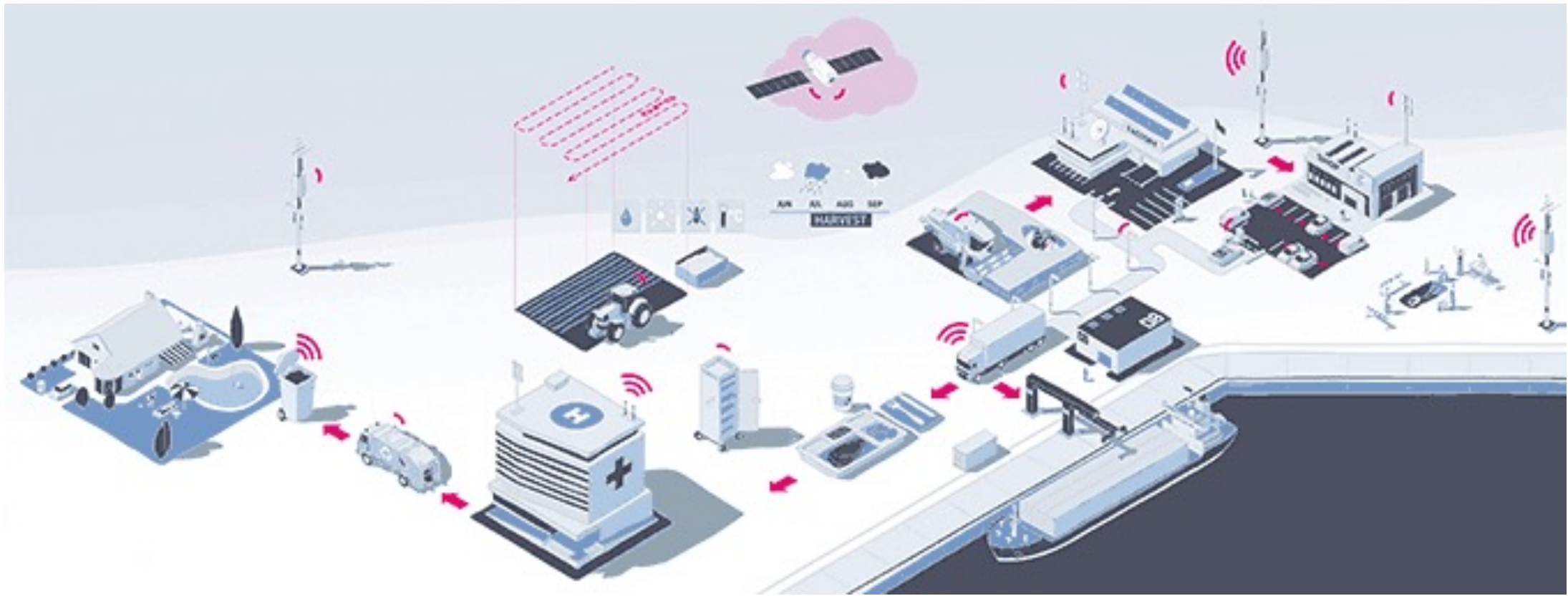
DEMONSTRATION OF INDUSTRY 4.0
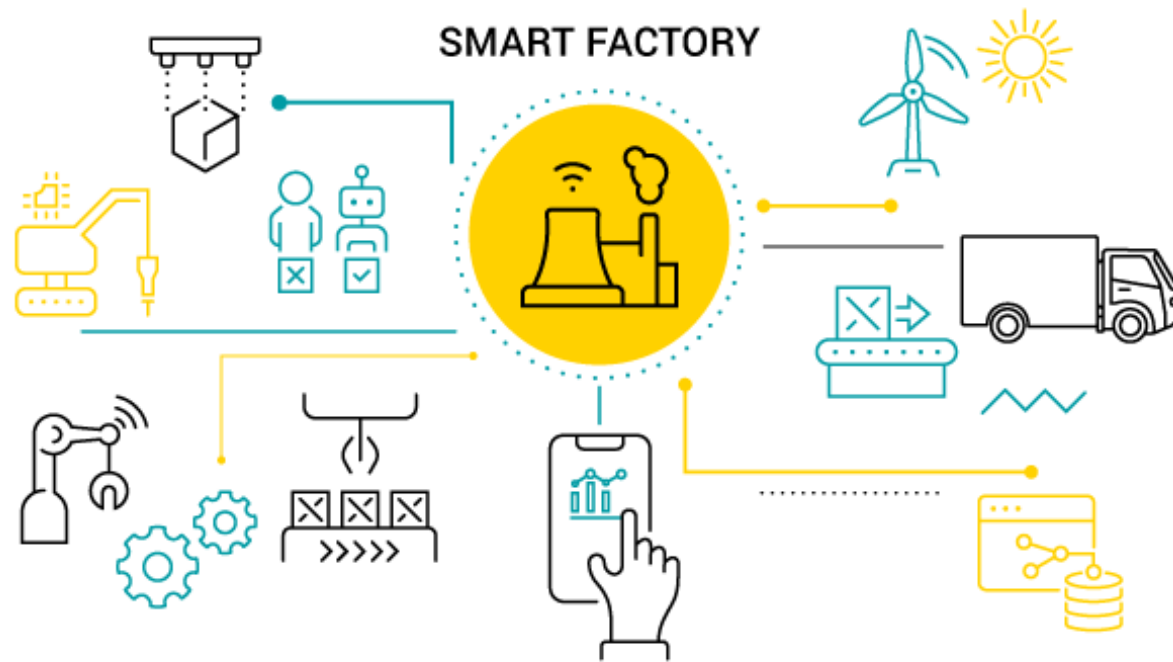
FUTURE PROSPECTS ON THE USE OF IoT

By 2025 it is estimated that **41,6 billion** artifacts with IoT

will be generating **79.4 zettabytes** (ZB)

Purpose

As business started to embrace Industry 4.0... along came Industry 5.0

- It is understood to recognise the power of industry to achieve **societal goals** beyond jobs and growth

- To become a resilient provider of prosperity, by
    - Making production respect the boundaries of the planet
    - Placing the wellbeing of the industry worker to the center of the production process

DIFFERENT FOCUS FROM 4.0

Highlights the importance of **research and innovation** to support the industry in its long term service to humanity within planetary boundaries

Industry
5.0

Towards a
sustainable,
human- centric
and resilient
European
industry

R&I PAPER
SERIES
POLICY BRIEF

- Since 2017 – academic efforts pushing industry 5.0

- 2021 – European commission

  - Directorate 'prosperity' of

  - Directorate-general for research and innovation

  - Top-down initiative in response to the changing societal and geopolitical landscape

WHAT IS INDUSTRY 5.0?

- Research and innovation
  drive the transition
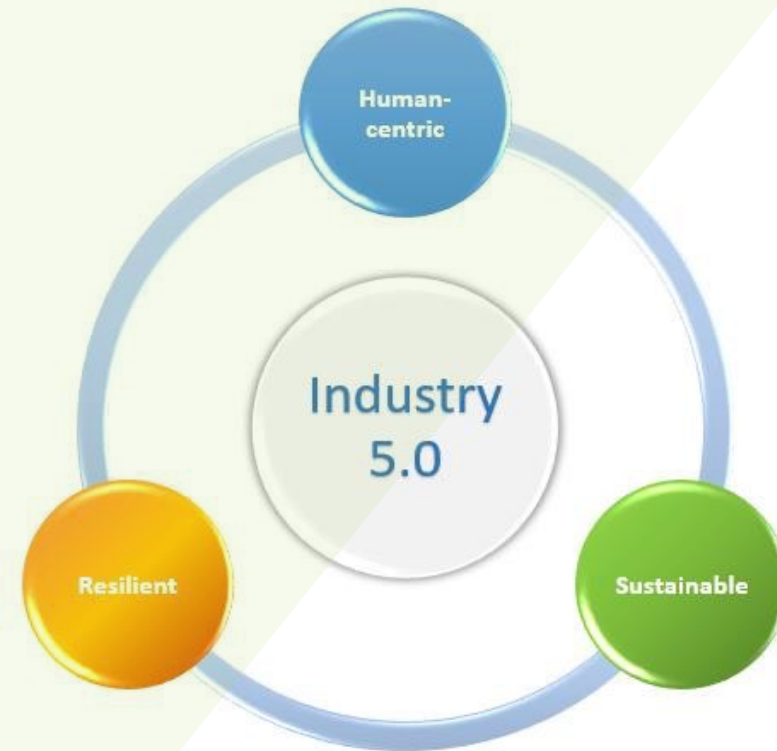
*'Industry 5.0 complements the existing Industry 4.0 paradigm by highlighting research and innovation as drivers for a transition to a sustainable, human-centric and resilient European industry. It moves focus from shareholder to stakeholder value, with **benefits** for all concerned.*

*Industry 5.0 attempts to capture the **value of new technologies**, providing prosperity beyond jobs and growth, while **respecting planetary boundaries**, and placing the wellbeing of the industry **worker at the centre** of the production process.'*

CORE 5.0 VALUES: HUMAN CENTRIC

- Human needs and interests at the heart of production

- Shift from technology-driven to a society-centric process

- Shift: workers as 'costs' to workers as 'investment'

- Technology adaptative to human needs

- Safe and inclusive work environments

  - Physical and mental health and wellbeing

  - Fundamental rights – autonomy, human dignity and privacy

- Workers need to upskill and reskill for better career opportunities and work-life balance

Industry 5.0

HUMAN-CENTRIC

… promotes talents, diversity and empowerment

RESILIENT

… is agile and resilient with flexible and adaptable technologies

SUSTAINABLE

… leads action on sustainability and respects planetary boundaries

LEAN &
HUMAN CENTRIC
RESEARCH

COLLABORATION & COMMUNICATION

Earlier

- Not especially emphasised, as division of work and the waterfall process assumed to suffice

- Throwing outputs over the wall to the next designer/expert

- Written and oral communication

Lean

- Emphasis to create the conditions for collaboration
  - Common ground
  - Standardised routines
  - Boundary objects
  - Sharing gains and pains

- Visual communication (visual management)
  - Provides common ground

Source: adapted from a presentation by Lauri Koskela

LAST PLANNER

Earlier

- CMP

- Command and control

- Designers make assumptions

- **Lean**

- Commitment plan

- Collaboration

- The project team develops a response

u-VITAL
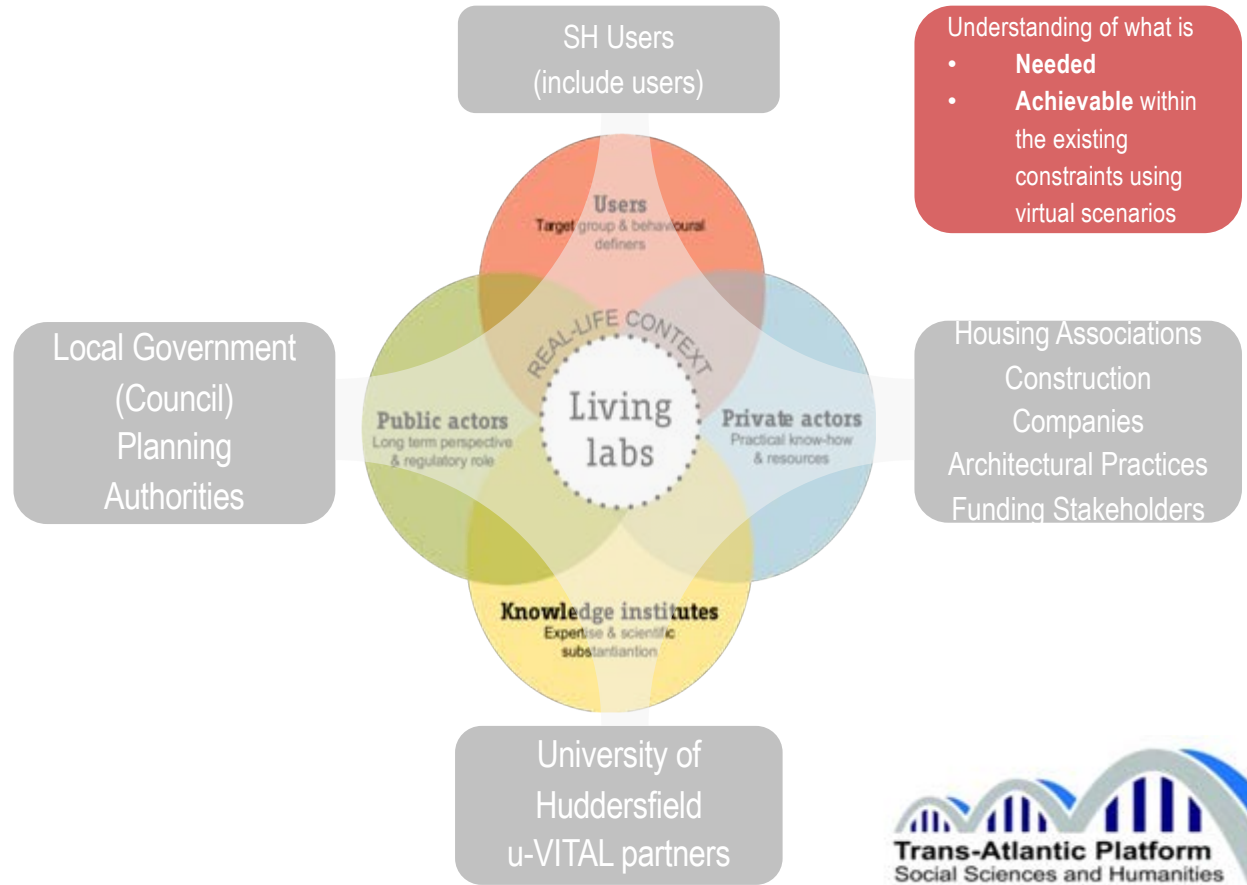
User-Valued Innovations for Social Housing upgrading through Trans-Atlantic Living Labs

Bridi, ME, Soliman-Junior, J, Granja, AD, Tzortzopoulos, P, Gomes da Silva, V & Kowaltowski, D 2022, 'Living Labs in Social Housing upgrades: Process, Challenges and Recommendations', *Sustainability*, vol. 14, no. 5, 2595. https://doi.org/10.3390/su14052595

(Steen & van Bueren 2017; adapted)

CORE 5.0 VALUES: SUSTAINABLE

- Circular processes that re-use, re-purpose and recycle natural resources

- Reduces waste and environmental impact

- Better resource efficiency and effectiveness

Industry 5.0

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Urgency of the transition to circular economy

Overconsumption and scarcity of natural resources

1 Earth

1970
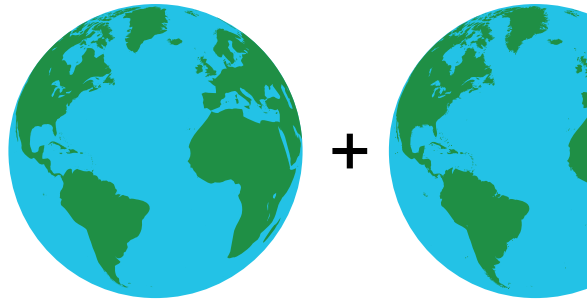
1.75 Earths

Today

3 Earths

2050

We move from a linear economy…   … to a circular economy

Take - Make - Dispose

Technical and biological
nutrients all mixed up

something useful

toxic
waste

Technical nutrients   Biological nutrients

Living systems

after W. McDonough and M. Braumgart
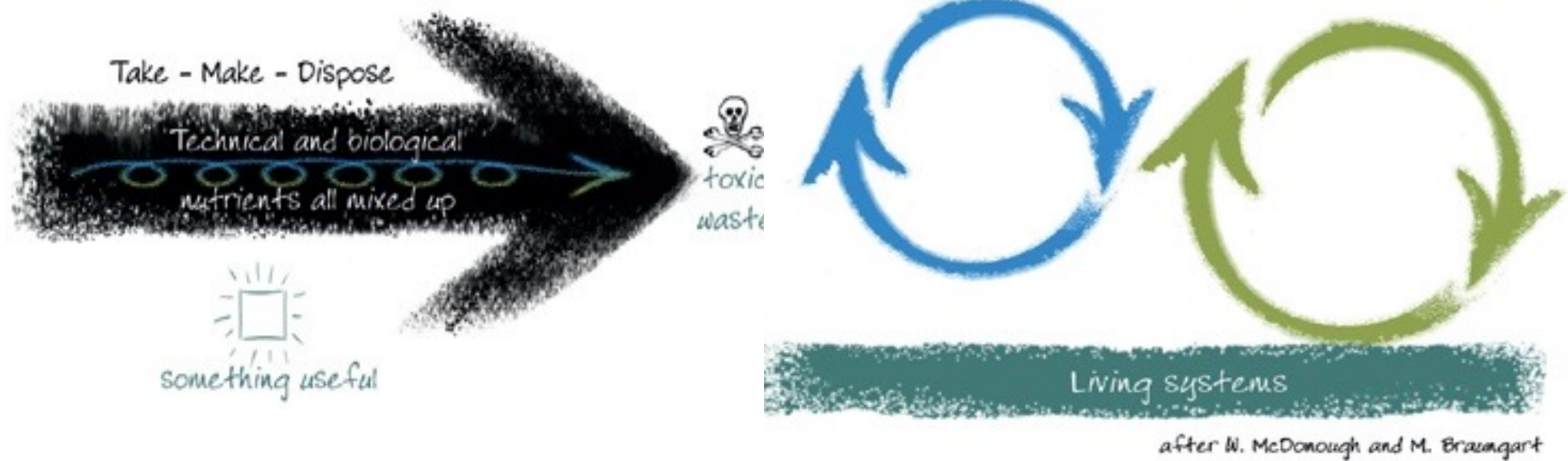
Levels of circularity: 10 R's

Order of priority

High

Low

- **Refuse: prevent raw materials use**
- **Reduce: decrease raw materials use**
- **Renew: redesign product in view of circularity**
- **Re-use: use product again (second hand)**
- **Repair: maintain and repair product**
- **Refurbish: revive product**
- **Remanufacture: make new product from second hand**
- **Re-purpose: re-use product but with other function**
- **Recycle: salvage material streams with highest possible value**
- **Recover: incinerate waste with energy recovery**

Current Dutch building development cycle is wasteful

The Dutch building sector is responsible for:

40% of total energy used

40% of primary resources used

40% of all waste
(24 million tons/year)

250 million tons of sand,
wood, concrete, steel each year

**Therefore the building sector is a major priority
in Dutch circular economy policies**

Example: The Concrete Agreement

CO2 low concrete
Geopolymers in Heiloo by TBI Mobilis

Less CO2 emissions in the building sector Electric
concrete mixer of Kijlstra

Less concrete in the building sector
3D printed bicycle bridge in Gemert by BAM

Reuse of concrete Rutte Groep and New Horizon
Urban Mining

CO2 low binder in concrete
Prefab production in housing construction by
Voorbij

Less CO2 emission in the building sector Electric
Excavator of Ploegam

DOES LEAN FULLY ADDRESS SUSTAINABILITY?

CORE 5.0 VALUES: RESILIENCE

- Higher degree of robustness in industrial production

- Better against disruptions

- Ensure it can provide critical infrastructure in times of crisis (including natural emergencies)

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Cynefin

Complex Un-order

Probe
Sense
Respond

Hidden Order

Sense
Analyse
Respond

Chaotic Un-order

Act
Sense
Respond

Visible Order

Sense
Categorise
Respond

- Cynefin and 'laws of simplicity'

- Resilience in recognition of chaos and complexity

Industry 5.0 Goals and technological enablers

- Individualised human-machine interaction technologies that inter- connect and combine the strengths of humans and machines

- Bio-inspired technologies and smart materials that allow materials with embedded sensors and enhanced features while being recyclable
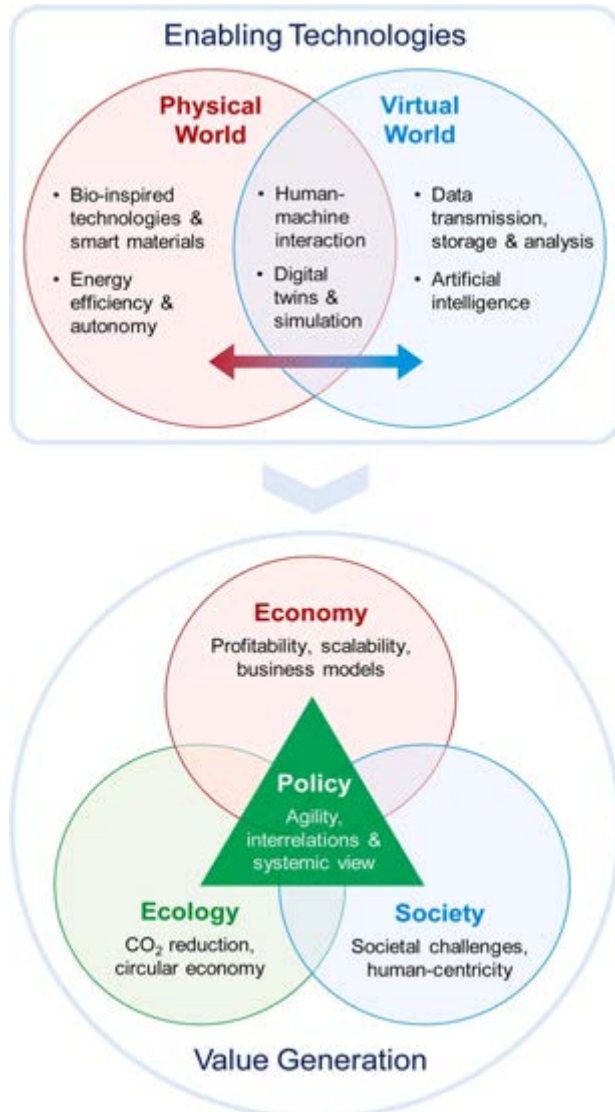
- Digital Twins and simulation to model entire systems

- Data transmission, storage, and analysis technologies able to handle data and system interoperability

- Artificial Intelligence to detect, for example, causalities in complex, dynamic systems, leading to actionable intelligence

- Technologies for energy efficiency, renewables, storage and autonomy

Villani V, Sabattini L, Baran ska P, Callegati E, Czerniak JN, Debbache A, et al. The INCLUSIVE system: a general framework for adaptive industrial automation. IEEE Trans Autom Sci Eng 2020.

Individualised human-machine interaction technologies that inter-connect and combine the strengths of humans and machines - Example

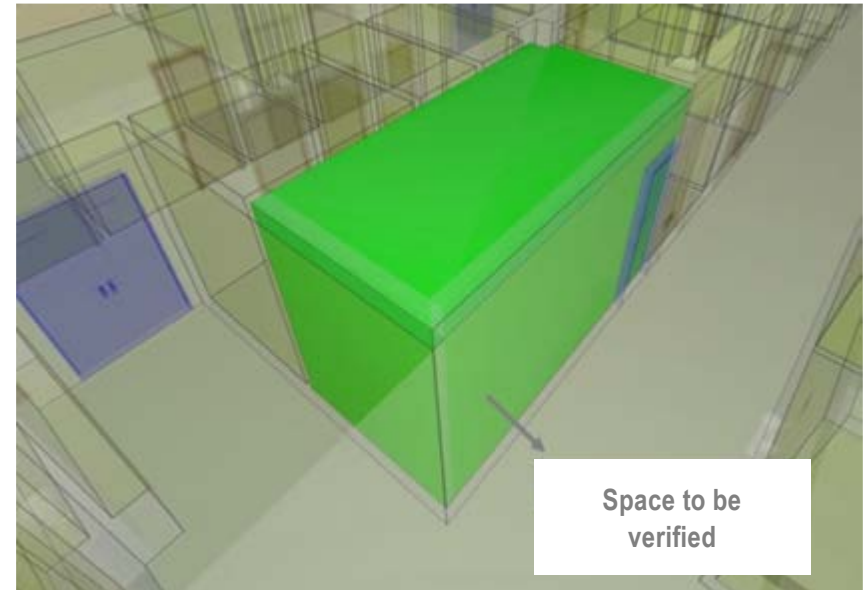# AUTOMATED CHECKING OF REGULATIONS AND REQUIREMENTS IN HEALTHCARE DESIGN

Automated rule-checking using Solibri Model Checker®

~ 85k requirements

The use of automated systems is promising – can provide more coherent results, with little or no ambiguity in assessment reports

Hybrid approach is needed – mistake proofing

Space to be verified

221 Requirements from HBN 11-01 could be verified by using Solibri Model Checker®

Requirements from HBNs and HTMs were inserted in Solibri, modelled and checked against a building model

Designers' perspective on the use of automation to support regulatory compliance in healthcare building projects
Soliman-Junior, J., Tzortzopoulos, P. & Kagioglou, M., 1 Feb 2022, In: Construction Management and Economics. 40, 2, p. 123-141 19 p.

Bio-inspired technologies and smart materials that allow materials with embedded sensors and enhanced features while being recyclable

Example: Eleksen

GPS / GSM

PROXIMITY WARNING SYSTEM

RADIO

GAS SENSOR

NOISE SENSOR

SMART CONNECTED HUB

Multiple sensors working together to improve worker safety, enforcing social distancing and improving productivity

Digital Twins and simulation to model entire systems

A digital twin, also called data twin, is a digital representation (model) of a real world object.
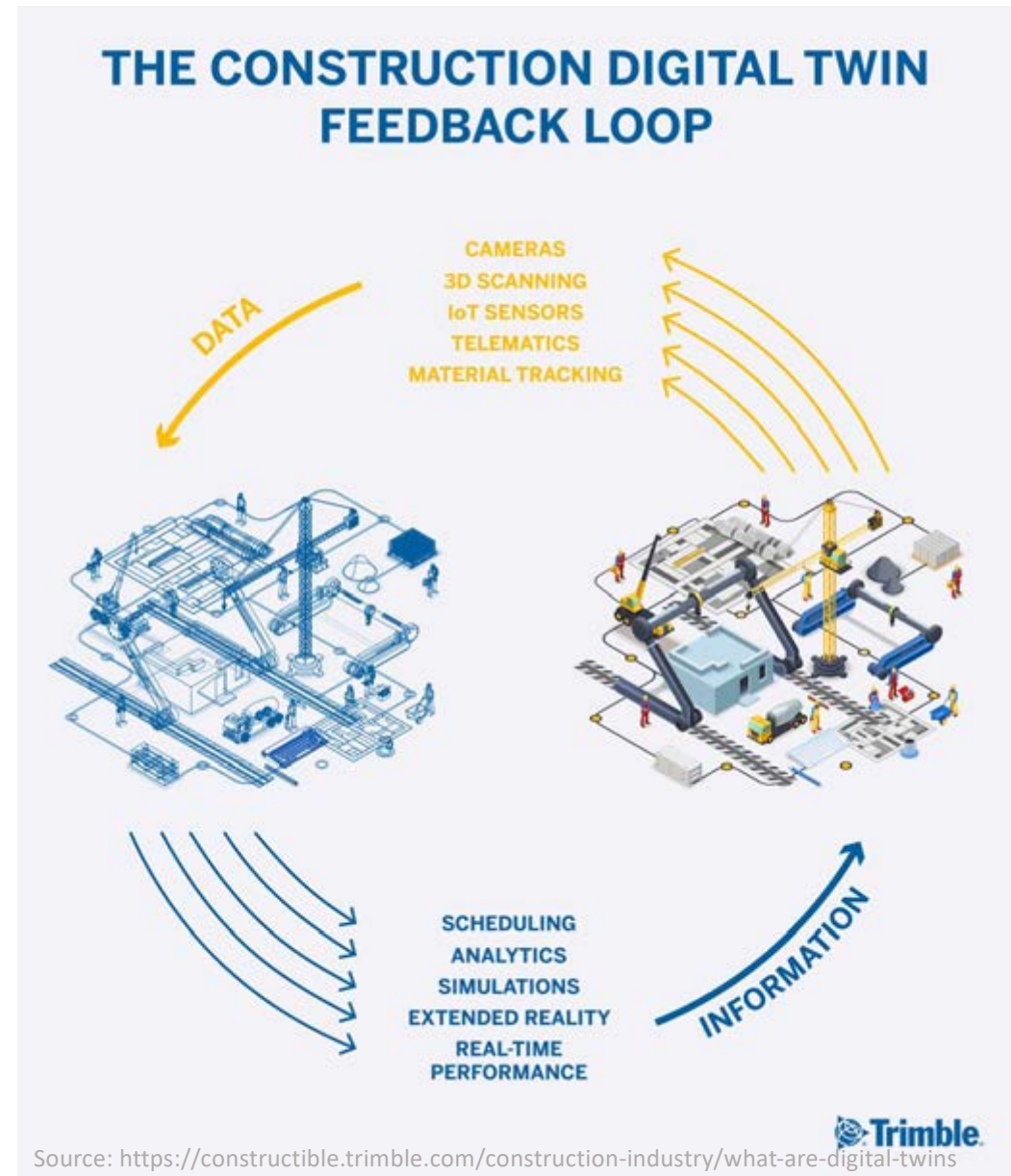
THE CONSTRUCTION DIGITAL TWIN FEEDBACK LOOP

DATA
- CAMERAS
- 3D SCANNING
- IoT SENSORS
- TELEMATICS
- MATERIAL TRACKING

INFORMATION
- SCHEDULING
- ANALYTICS
- SIMULATIONS
- EXTENDED REALITY
- REAL-TIME PERFORMANCE

Trimble

Source: https://constructible.trimble.com/construction-industry/what-are-digital-twins

Artificial Intelligence to detect, for example, causalities in complex, dynamic systems, leading to actionable intelligence

- AI to prevent cost overruns

- AI for better design through generative design

- AI to improve jobsite productivity

- AI for site safety

- …

Machine Learning
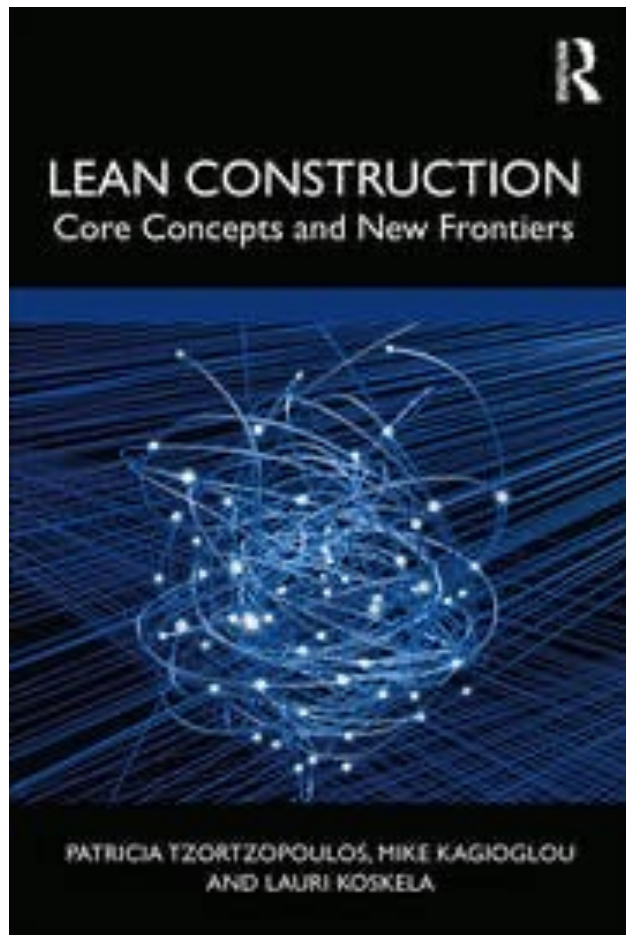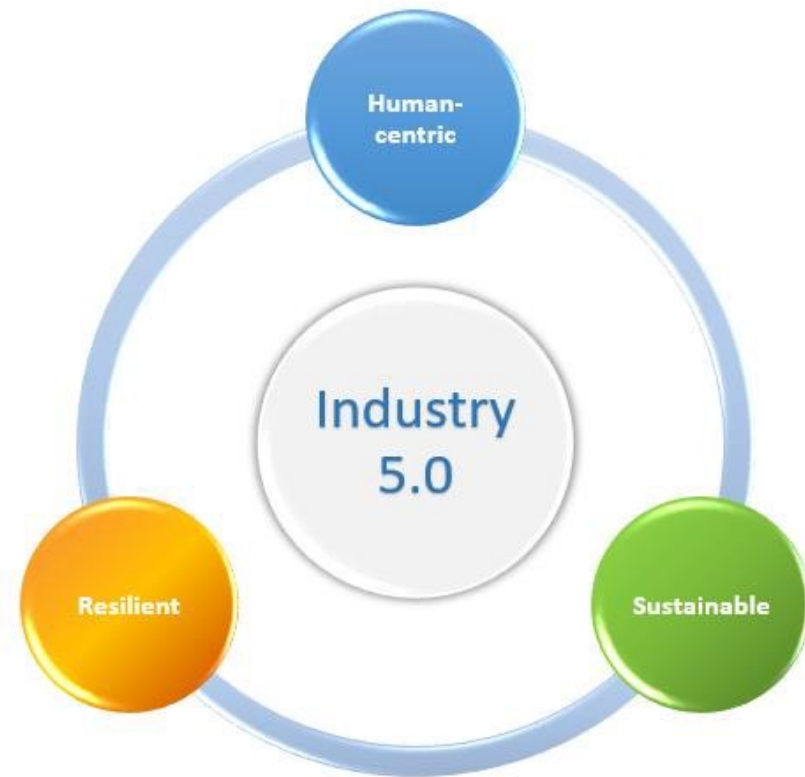Deep Learning
Computational Intelligence
Neural Computing
Evolutionary Computation

Human-Machine Interaction
Reinforcement learning
Multi-modal Human-robot Interaction
Metaverse
Brain–Machine Interface
Collaborative AI Systems
......

Cognitive Computing
Genomics
Computational Biology
Molecular Biology
DNA Computing
Bioinformatics
Neuroscience
Health Informatics
......

Complex Systems

Complex Systems and Artificial Intelligence

Edited by
Qiang Zhang and Yifeng Zeng

Topic Published in
Applied Sciences, Entropy, Sensors, Genes
and Journal of Personalized Medicine

https://www.mdpi.com/topics/Complex_Systems_AI

Links with Industry 5.0

LEAN CONSTRUCTION – NEW FRONTIERS

- Important role of research and innovation to support industry achieve Industry 5.0 goals

- Focus of work – clearly defined… impact clearly identified

- Focus on true multidisciplinarity

- Why do research?
  - Societal goals and grand challenges
  - Look outside lean to bring practices and knowledge from other areas
  - Effectiveness x efficiency in research (and methods)

- Establish a theoretical common ground between lean and other areas
  - Philosophical discussion – why visual management works? creativity? Why TVD works, is it about enabling people to make better decisions? Having more time incentive, creativity and understanding

- *Why waste not acknowledged? An ontology that does not enable elimination of waste, does not allow seeing how waste emerges* (Koskela)

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Thank you!

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