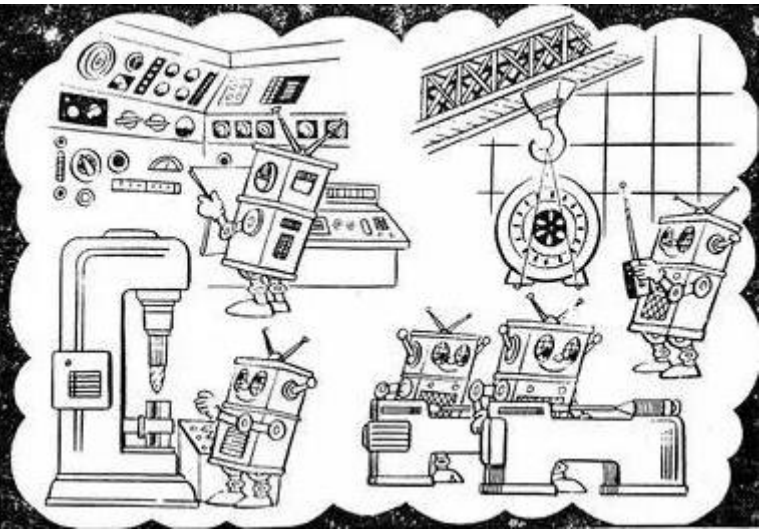
Construction robotics 2030

Motivation




47 我试着吃了几粒，嗨！有点饭的味道，但又和饭不同。
餐桌上的菜很丰盛，什么清蒸肉丸、红烧肉、五香酱蛋等等。
那酱蛋足足有小西瓜那么大，我吃了一块味道有点象鸡蛋，
但比鸡蛋还鲜。


机器人出诊


DORAEMON ★ FLY HIGH
dora-world.com

Start from reviewing ISARC papers

- What are people concerning in the field of construction robotics field?
- ISARC
  - International Symposium for Automation and Robotics in Construction
  - Held by IAARC (International Association for Automation and Robotics in Construction)
  - From 1984; 2012 in Eindhoven
  - 3000+ papers in 30 years

Problem and objectives

- Lack of an overview of the whole picture of the technical innovations in construction robotics
- Lack of an exploration of the possible future of construction robotic technologies

- **state of the art** of the technical innovations' application
- **future landscapes** of technologies in construction robotics.

Main research question:

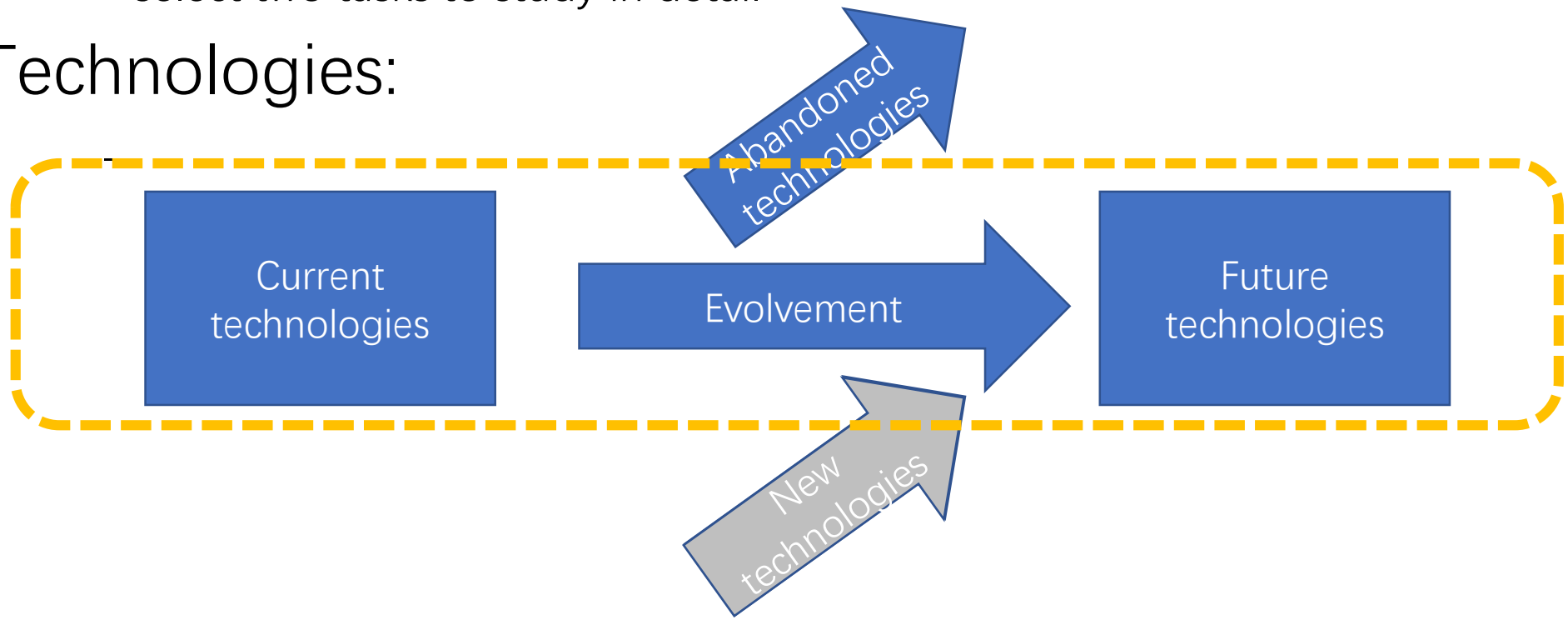
In the Dutch construction industry, **what technologies are available to enhance the robotics level** and **what are the possible futures of technical innovations in construction robotics in 2030?**

Research question

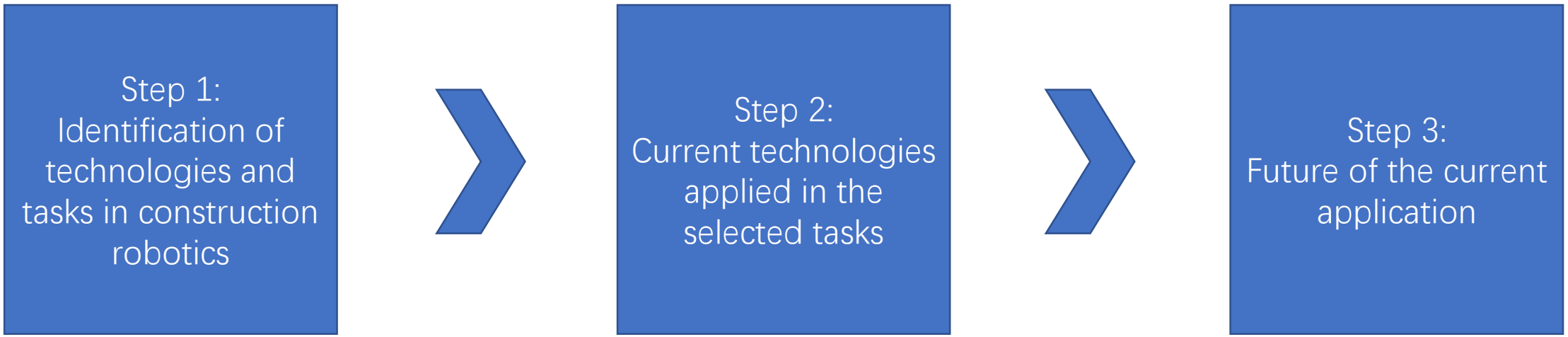
- In the Dutch construction industry, **what technologies are available to enhance the robotics level** and **what are the possible futures of technical innovations in construction robotics in 2030?**

Limitation

- Tasks:
  - limited time
  - select two tasks to study in detail
- Technologies:
  -



Research process



Step 1:
Identify the tasks and technologies in construction robotics

Method

- Systematic literature review;
- ISARC papers as the main resource;
- 572 papers from 2012 to 2016;
- 255 papers are about specific technologies' application
- Groups of the papers according to the tasks they contribute to and technologies they use:

	CPS/IoT	RFID	A&R	MD	AM	PLM	HCI	S&A	BIM	VR	CC	BD	MC	SM	LS	other	Number*
Earthwork	2	1	7	0	0	0	0	3	3	0	0	0	1	0	1	9	7
Reinforcement	0	0	1	0	0	0	0	1	2	0	0	0	0	0	0	0	3
Paving	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0
Concrete distribution	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Concrete finishing	0	0	1	0	1	0	0	2	0	0	0	0	0	0	0	1	3
Welding	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Coating	0	0	5	0	0	0	0	0	0	0	0	0	0	0	0	0	1
Assembly	1	0	6	1	0	0	0	3	1	1	0	0	0	0	2	3	7
Interior finishing	2	0	1	0	0	0	0	0	0	0	0	0	0	0	1	0	3
Masonry	0	0	1	0	0	0	0	0	1	0	0	0	0	0	0	0	1
Surveying and monitoring	9	0	4	0	0	0	0	2	2	0	1	0	1	0	3	4	7
Logistics	2	0	4	0	0	0	0	11	2	0	0	0	0	0	1	4	5
Site planning and management	2	4	1	0	0	0	0	10	5	1	0	0	2	0	5	6	8
Safety	7	0	4	0	0	0	0	7	2	3	1	3	0	0	1	15	8
Quality control	0	0	2	0	0	0	0	0	1	0	0	0	0	0	6	4	3
process management	3	0	2	0	0	2	1	9	4	1	2	0	2	0	1	10	10

Identified tasks

16 construction tasks

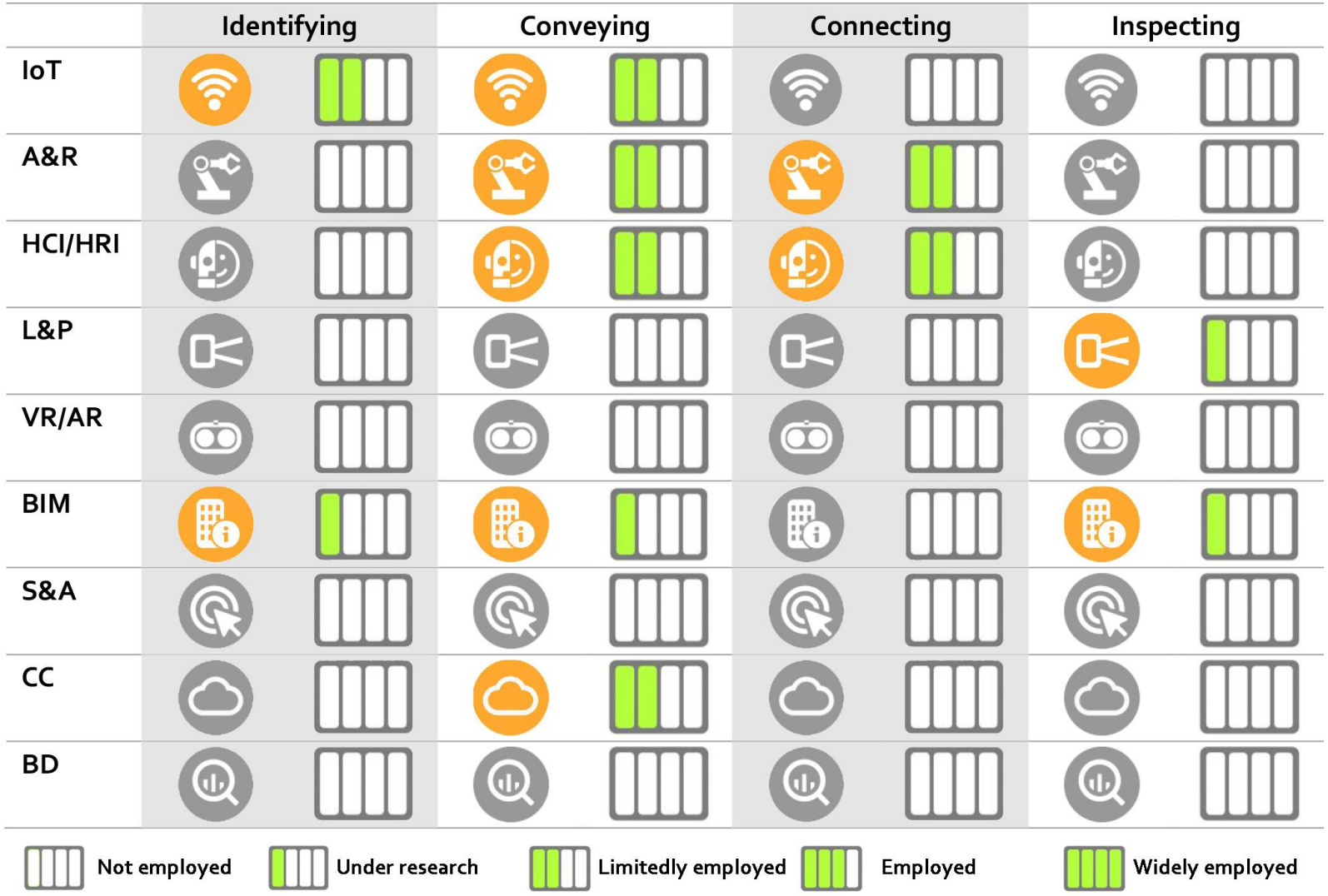
Identified tasks in the onsite construction work	
Cluster	Tasks
First type: directly related to the physical production	Earthwork
	Reinforcement
	Paving
	Concrete distribution
	Concrete finishing
	Welding
	Coating
	Assembly
	Interior finishing
	Masonry
Second type: related to the construction process	Surveying and monitoring
	Logistics
	Site planning and management
	Safety
	Quality control
	Process management

Identified technologies

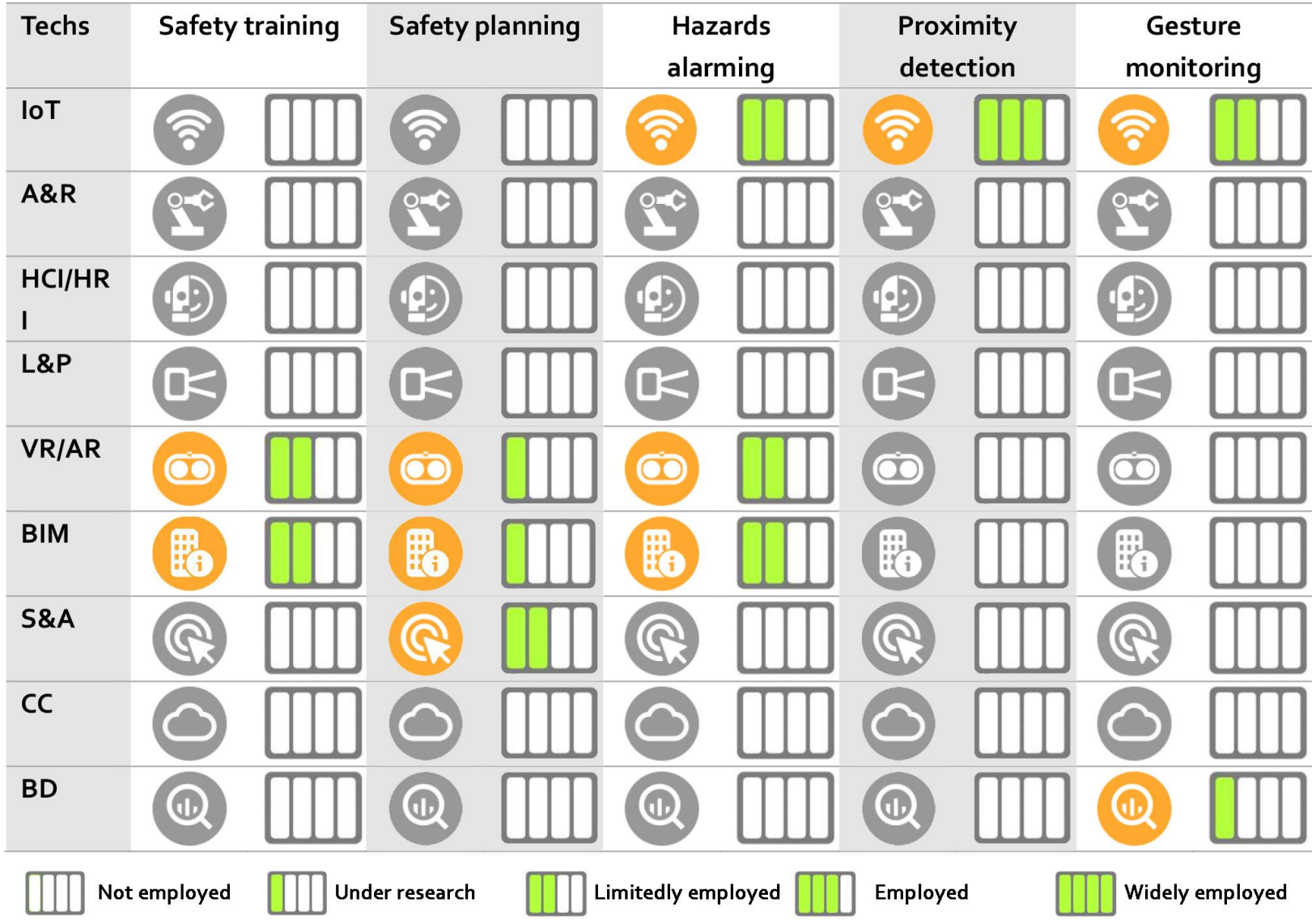
Technology	Abb.	Icon	Technology	Abb.	Icon	Technology	Abb.	Icon
Internet of Things	IoT		Human-Computer/Robot Interaction	HCI /HRI		Simulation and Algorithm	S&A	
Additive Manufacturing	AM		Laser Scanning and Photogrammetry	L&P		Cloud Computing	CC	
Modularisation and Prefabrication	M&P		Virtual Reality /Augmented Reality	VR /AR		Big Data	BD	
Automation and Robot	A&R		Building Information Modelling	BIM				

Step 2:
Current technologies

Current technologies: construction assembly



Current technologies: construction safety

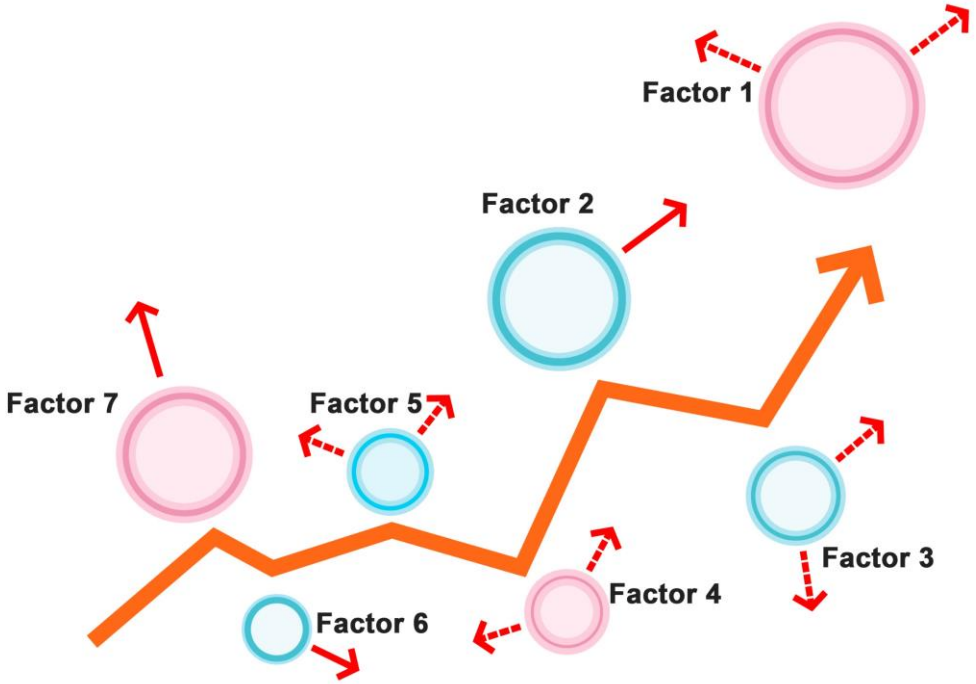


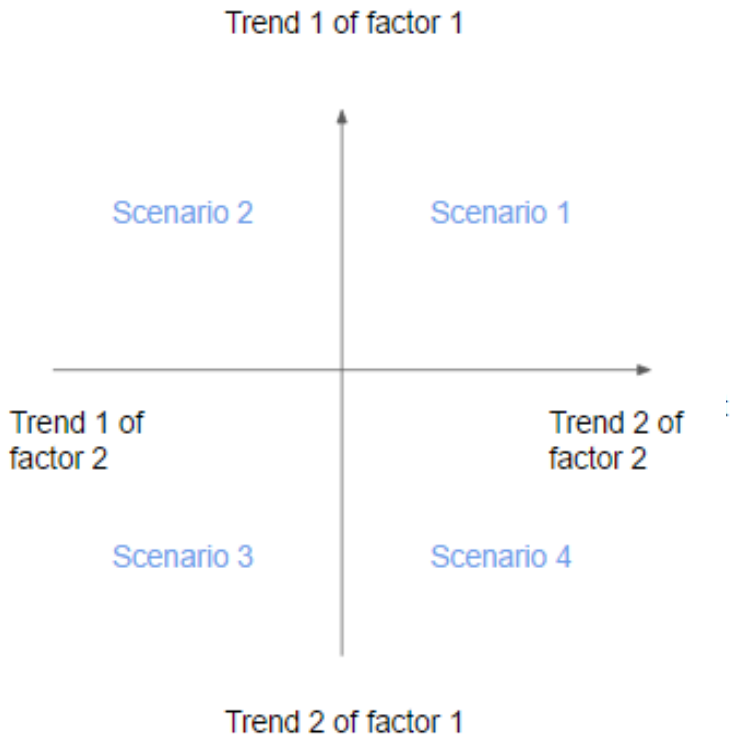
Step 3:
Future study

Sub questions and Research methods

- Sub question 3: What are the possible landscapes of construction robotic technologies in the Netherlands in 2030?

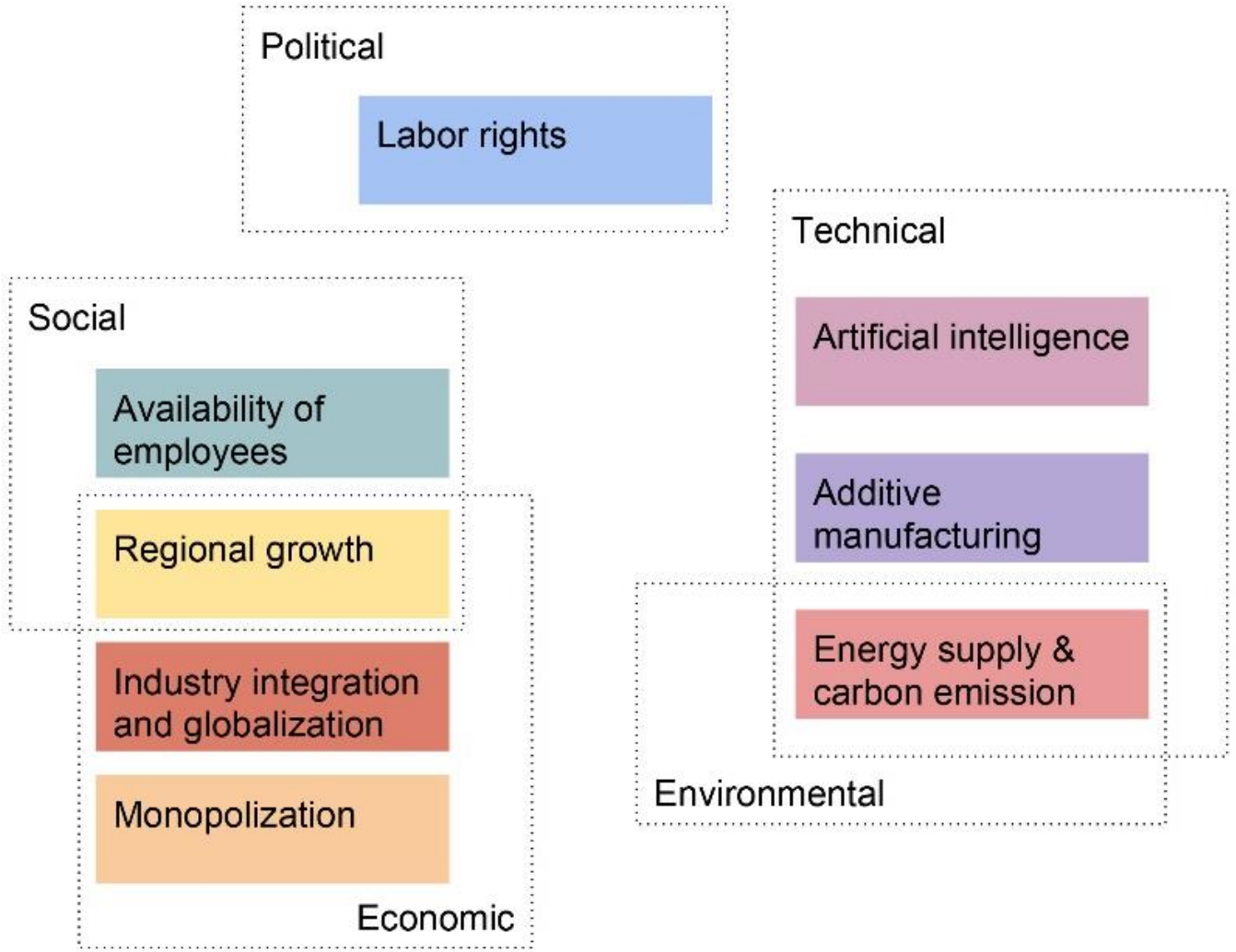
  - scenario planning based method





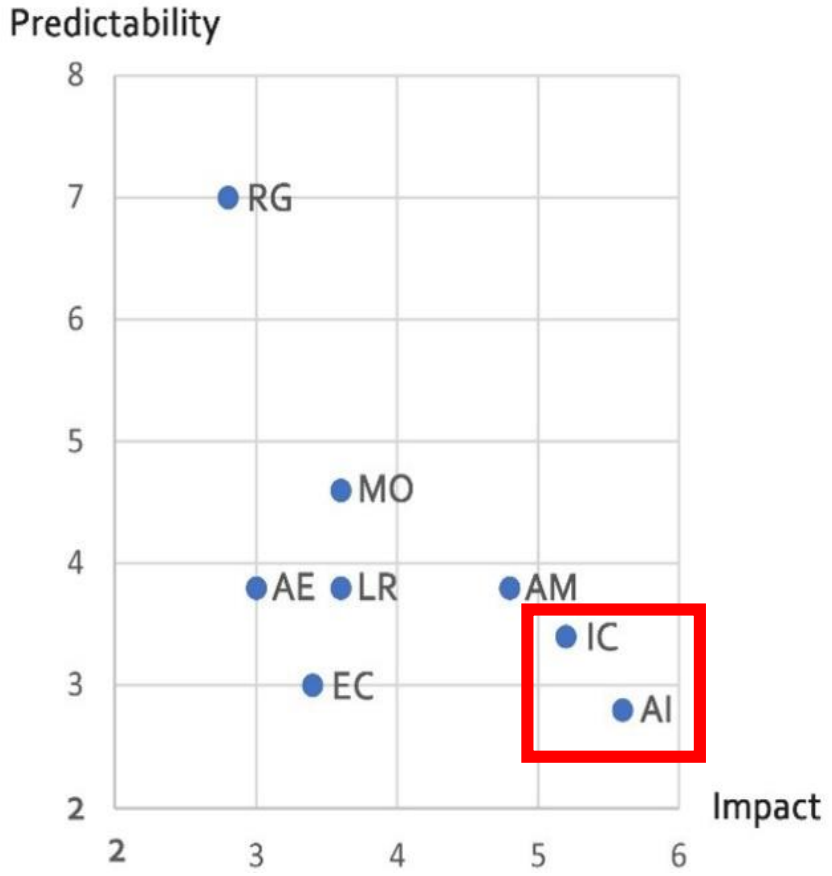
Future studies–factors identifying

Future studies–scenario planning



Future studies–scenario planning

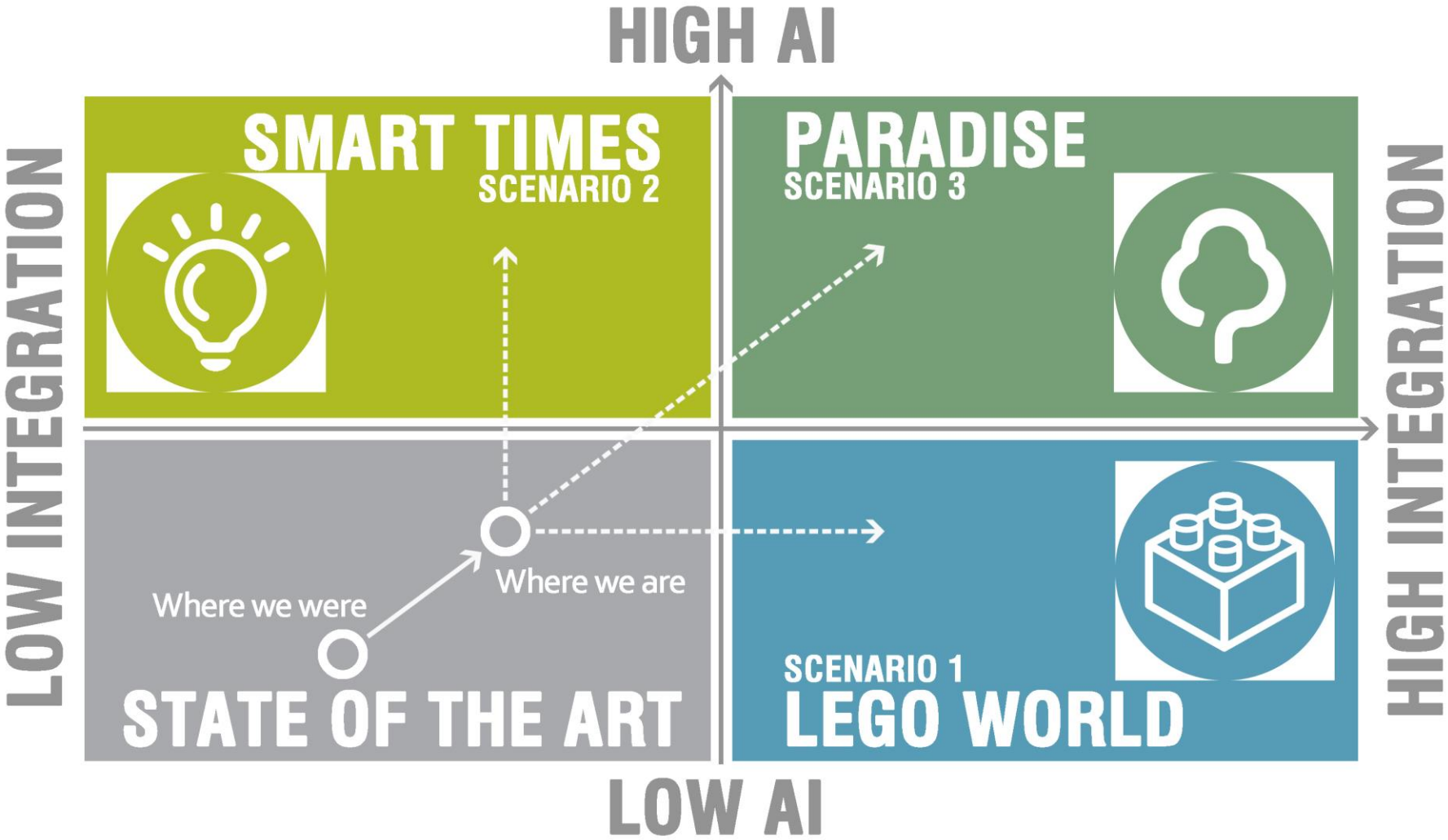
	Impact	Predictability
Labor right (LR)	3.6	3.8
Artificial intelligence (AI)	5.6	2.8
Additive manufacturing (AM)	5	3.6
Energy supply & carbon emission (EC)	3.4	3
Availability of employees (AE)	3	3.8
Regional growth (RG)	2.8	7
Integration of construction (IC)	5.2	3.4
Monopolization (MO)	3.6	4.6



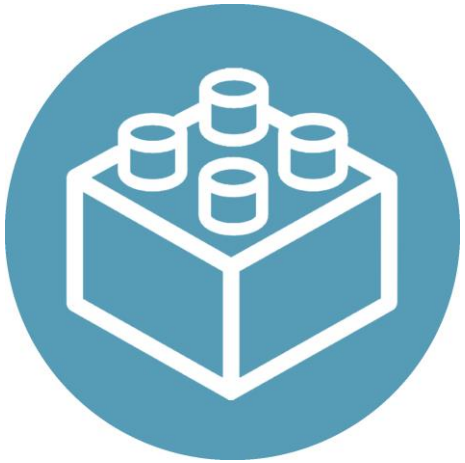
Future studies–scenario planning

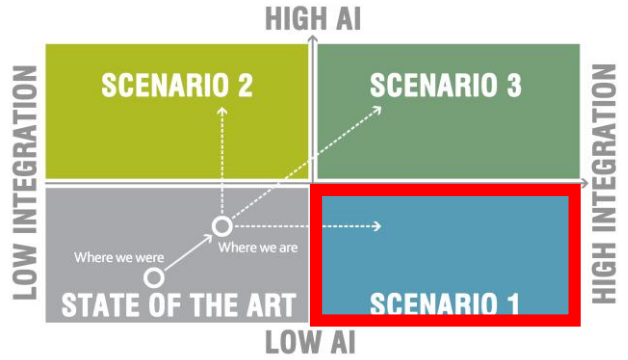
- Artificial Intelligence
- Integration of the construction industry
    - construction industry: highly fragmented;
    - product level: uniqueness of each project;
    - process level: process of each product is different;
    - market level: thousands of contractors on market;
    - the manufacturing industry: standard product > standard process > fewer suppliers;
    - integration of the construction industry: working more like the manufacturing industry.

Scenario planning – Matrix



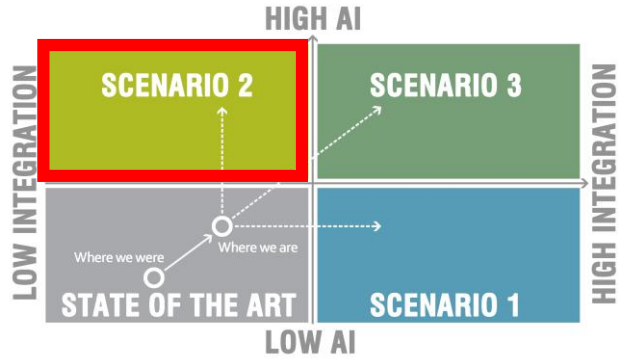
Scenario 1





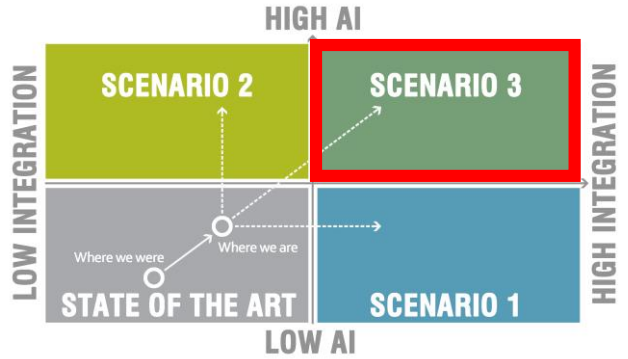
- Brandization and standardization in small and simple buildings;
- Large buildings: higher level of prefabrication;
- Market and process integration: fewer and bigger players;
- Most of the works have been moved into factories , but human workers still dominant the onsite works;
- Globally-distributed massive production is introduced into the construction industry.

Scenario 2



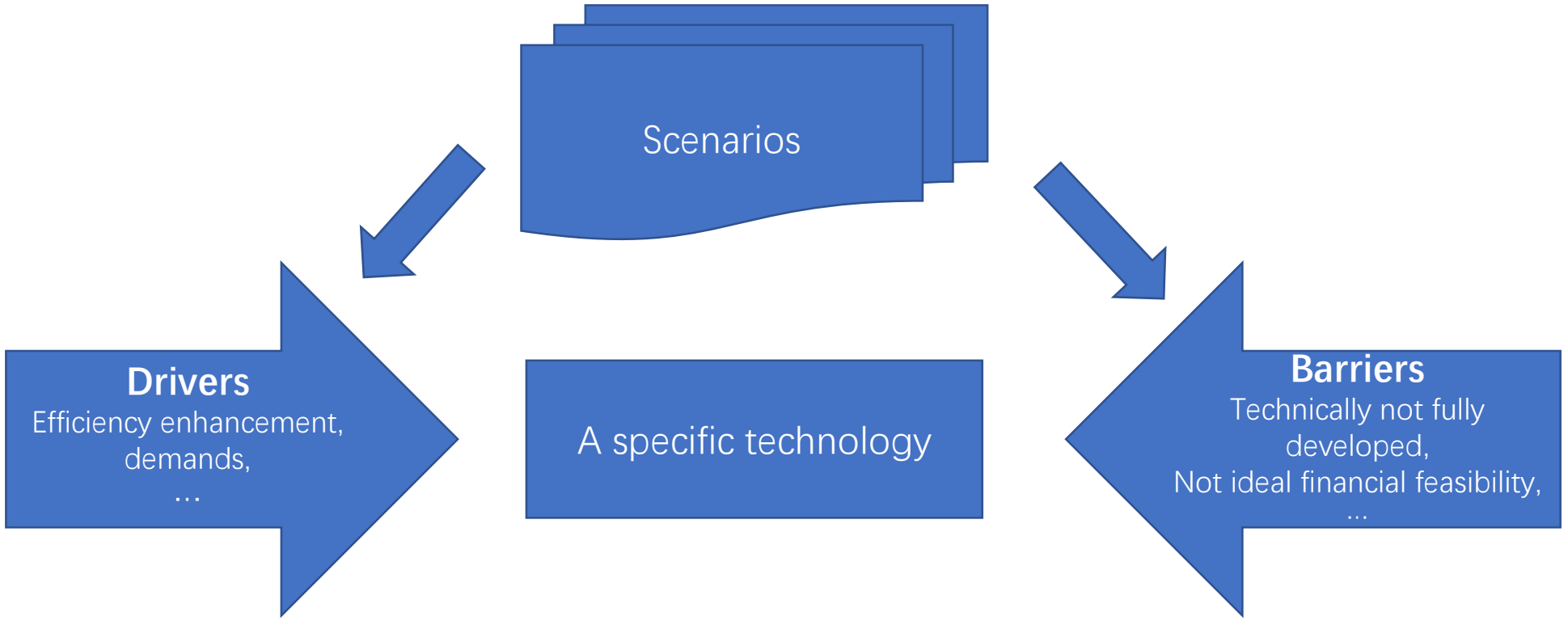
- AI-supported highly automatic onsite construction process;
- Wide application of robots and the reduced demands for labors;
- Information technologies dominate the construction;
- Many small companies survive;
- Construction robotics is applied in maintenance and renovation projects.

Scenario 3



- Highly automatic building process, high standard level of the construction industry;
- Customization as a popular business model;
- Medium monopolization;
- Localized production.

Evolvement of technologies



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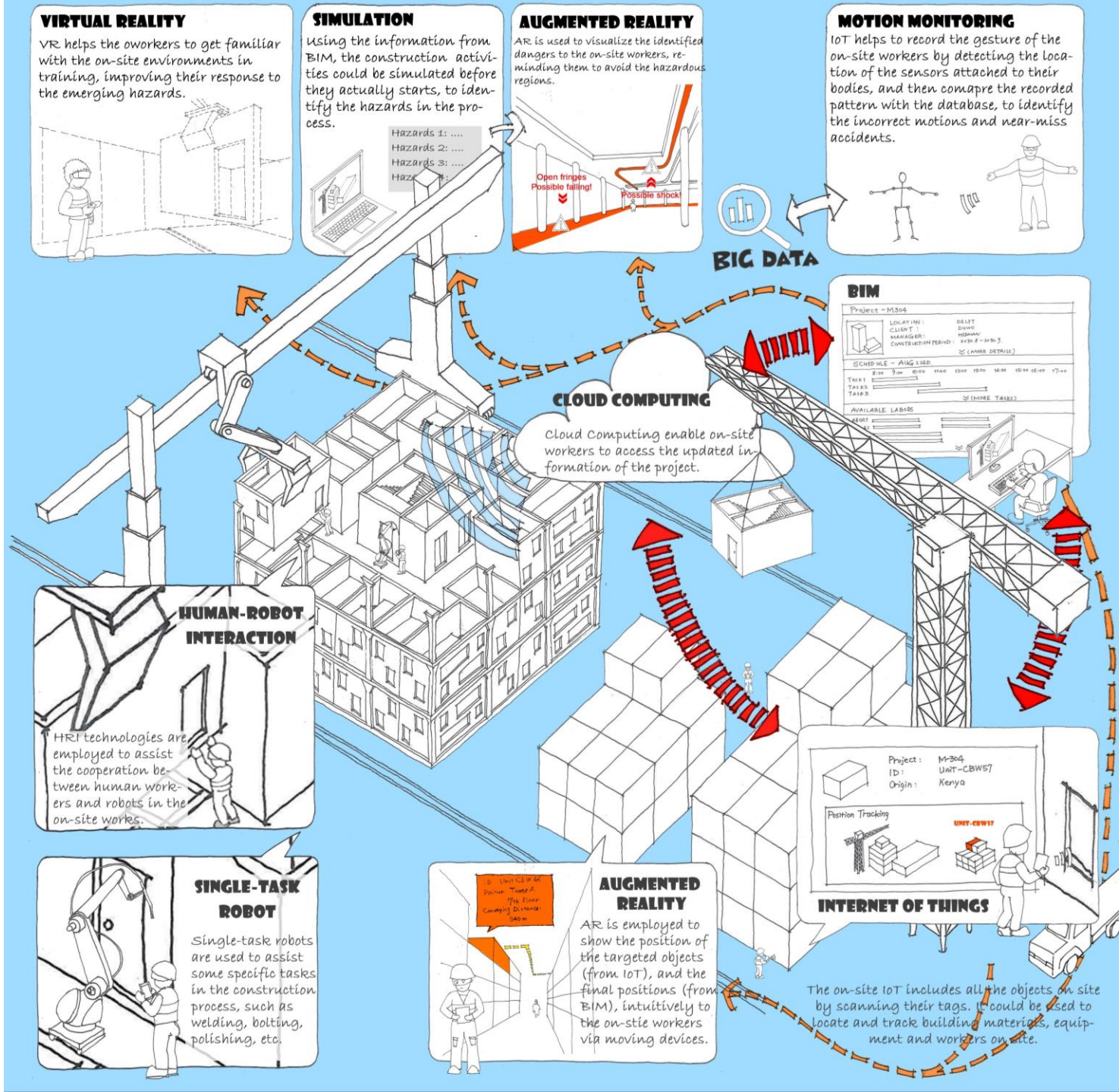
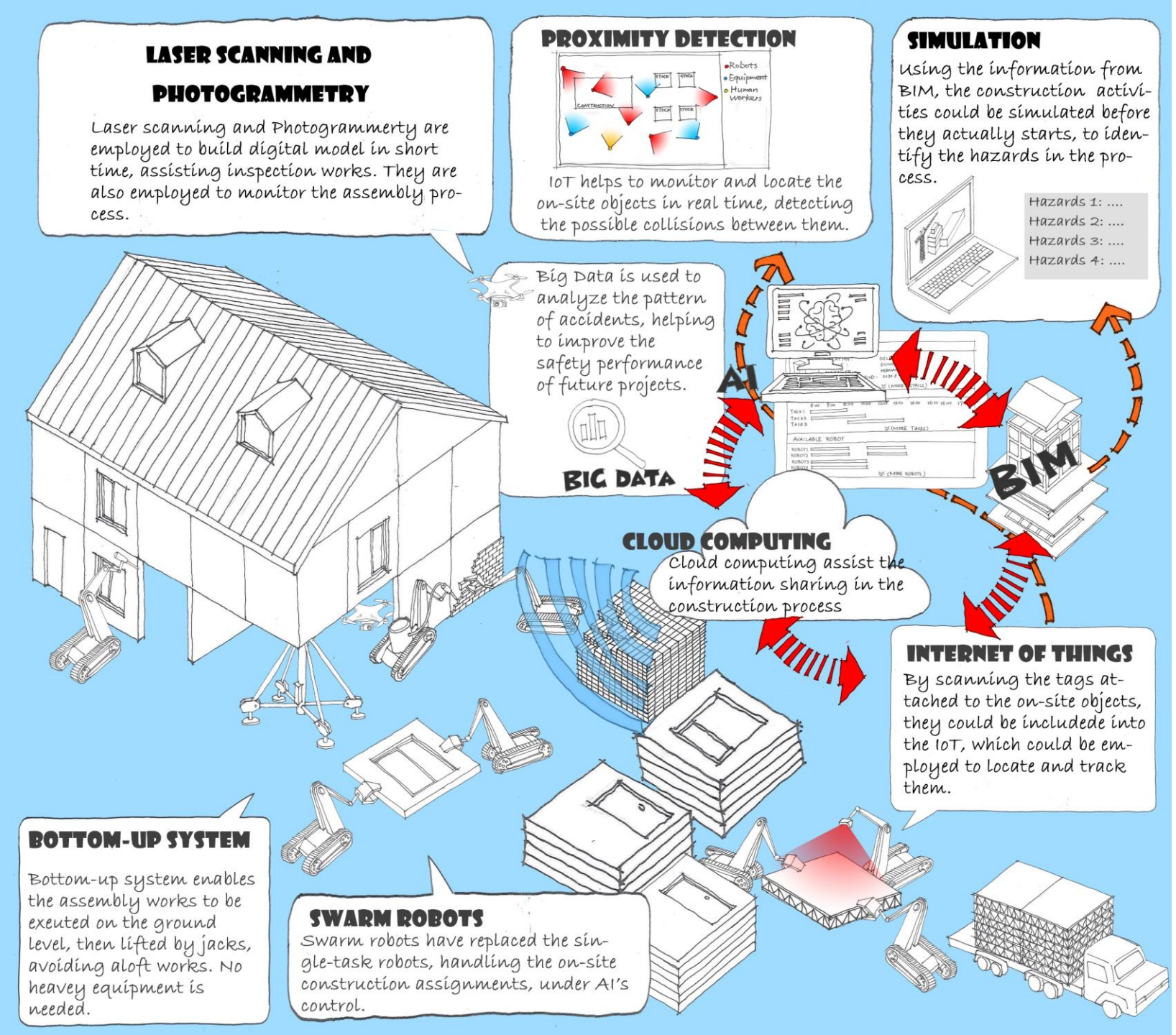
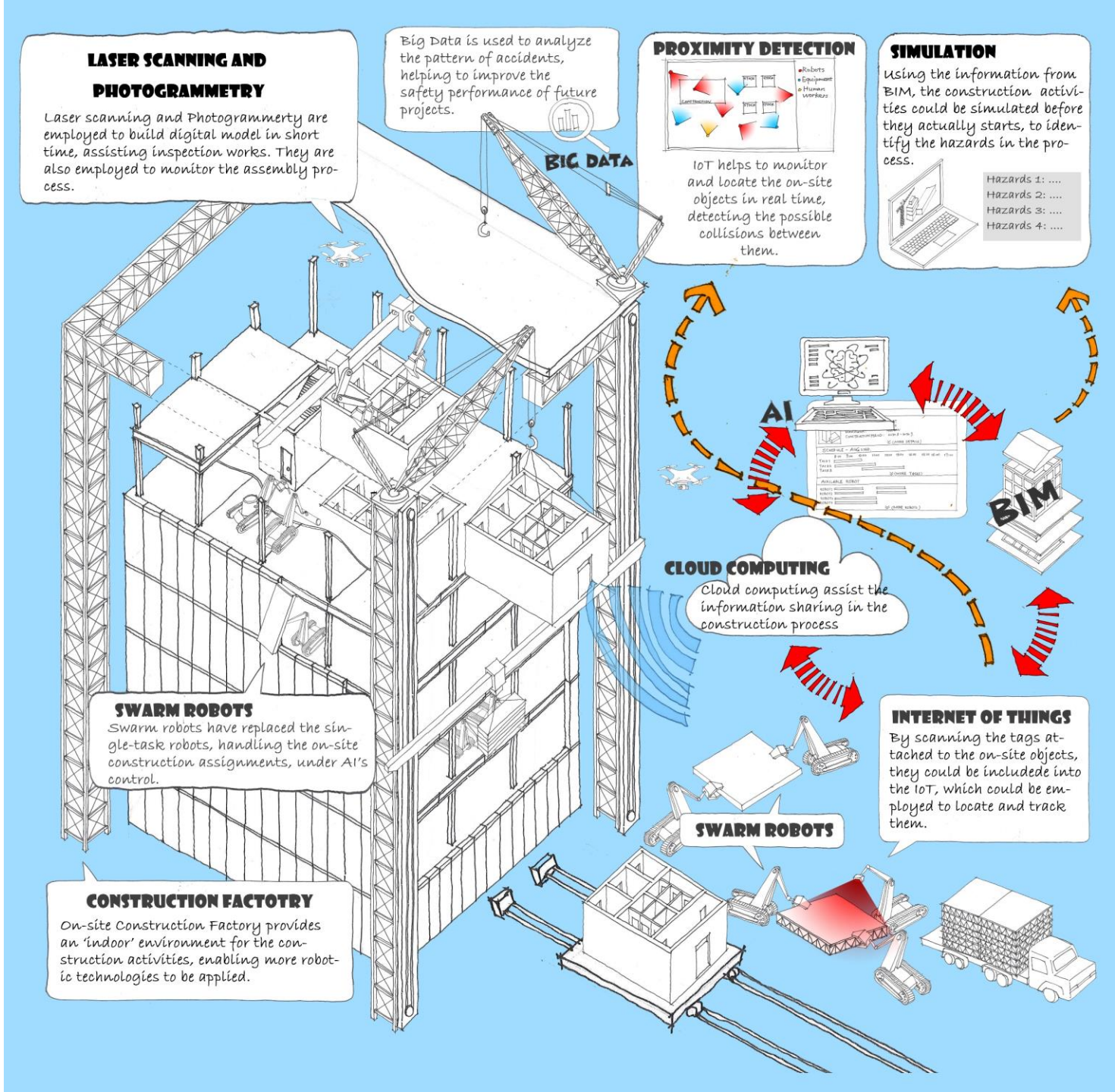

VIRTUAL REALITY
VR helps the oworkers to get familiar with the on-site environments in training, improving their response to the emerging hazards.
SIMULATION
Using the information from BIM, the construction activities could be simulated before they actually starts, to identify the hazards in the process.
Hazards 1: ....
Hazards 2: ....
Hazards 3: ....
AUGMENTED REALITY
AR is used to visualize the identified dangers to the on-site workers, reminding them to avoid the hazardous regions.
Open fringes
Possible falling!
Possible shock!
MOTION MONITORING
IoT helps to record the gesture of the on-site workers by detecting the location of the sensors attached to their bodies, and then comapre the recorded pattern with the database, to identify the incorrect motions and near-miss accidents.
BIG DATA
BIM
CLOUD COMPUTING
Cloud Computing enable on-site workers to access the updated information of the project.
HUMAN-ROBOT INTERACTION
HRI technologies are employed to assist the cooperation between human workers and robots in the on-site works.
SINGLE-TASK ROBOT
Single-task robots are used to assist some specific tasks in the construction process, such as welding, bolting, polishing, etc.
AUGMENTED REALITY
AR is employed to show the position of the targeted objects (from IoT), and the final positions (from BIM), intuitively to the on-stie workers via moving devices.
Project : M-304
ID : UNIT-CBW57
Origin : Kenya
Position Tracking
INTERNET OF THINGS
The on-site IoT includes all the objects on site by scanning their tags. It could be used to locate and track building materials, equipment and workers on site.


LASER SCANNING AND PHOTOGRAMMETRY
Laser scanning and Photogrammerty are employed to build digital model in short time, assisting inspection works. They are also employed to monitor the assembly process.
PROXIMITY DETECTION
Robots
Equipment
Human workers
IoT helps to monitor and locate the on-site objects in real time, detecting the possible collisions between them.
SIMULATION
Using the information from BIM, the construction activities could be simulated before they actually starts, to identify the hazards in the process.
Hazards 1: ....
Hazards 2: ....
Hazards 3: ....
Hazards 4: ....
Big Data is used to analyze the pattern of accidents, helping to improve the safety performance of future projects.
BIG DATA
AI
BIM
CLOUD COMPUTING
Cloud computing assist the information sharing in the construction process
INTERNET OF THINGS
By scanning the tags attached to the on-site objects, they could be includede into the IoT, which could be employed to locate and track them.
BOTTOM-UP SYSTEM
Bottom-up system enables the assembly works to be exeuted on the ground level, then lifted by jacks, avoiding aloft works. No heavey equipment is needed.
SWARM ROBOTS
Swarm robots have replaced the single-task robots, handling the on-site construction assignments, under AI's control.

Scenario 2

Scenario 3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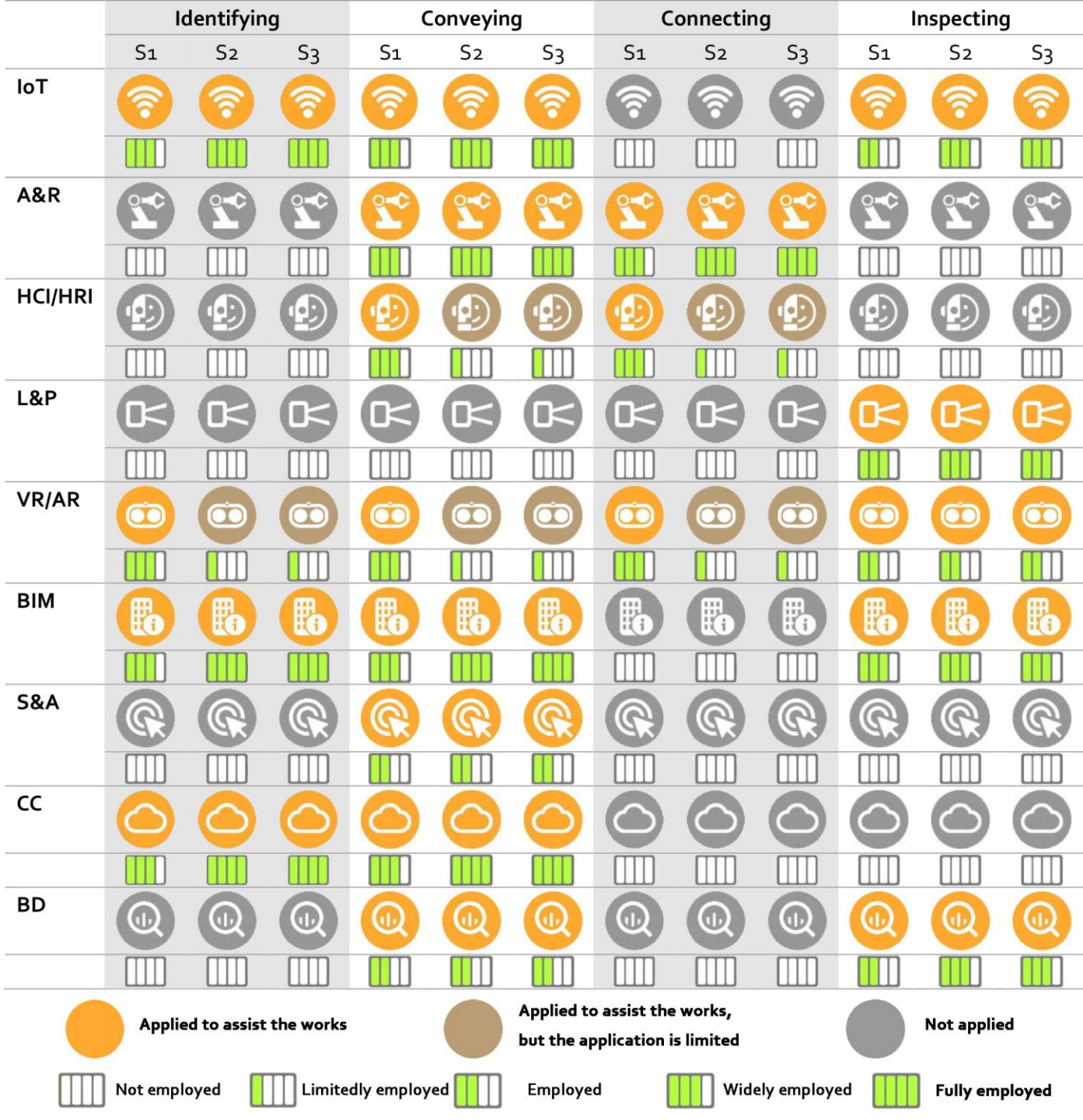
SWARM ROBOTS
CONSTRUCTION FACTOTRY
On-site Construction Factory provides an 'indoor' environment for the construction activities, enabling more robotic technologies to be applied.

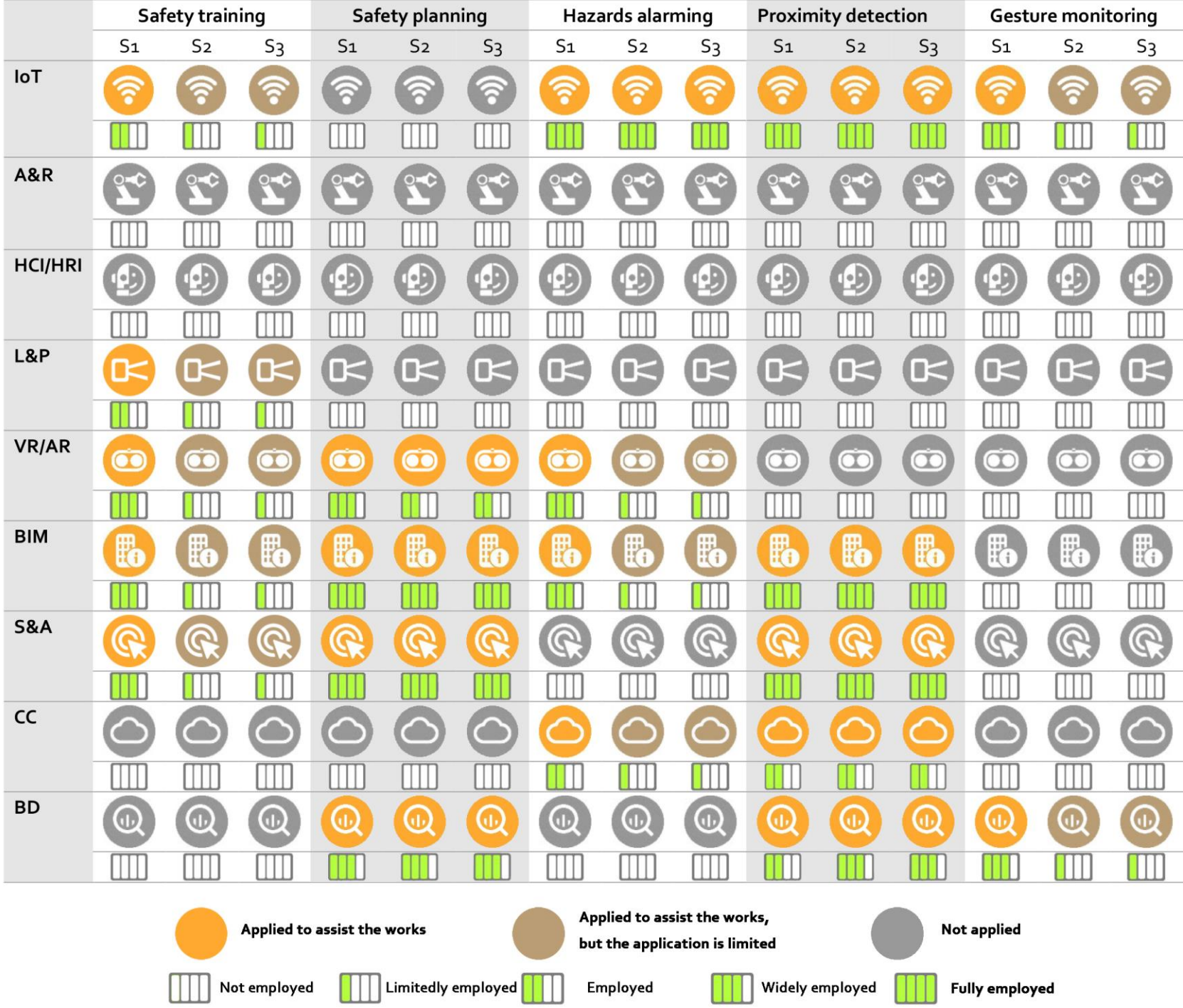
Overlap

- Scenario 1 vs Scenario 2&3
- Technologies related to human intervention decrease;
- CF most used in Scenario 1 and Bottom-up system most used in Scenario 2.
- Cloud computing is applied in Scenario 2 and 3.
- Overlap: wireless sensing, BIM, robots, laser scanning
- In scenario 2&3: evolve to the direction of swarm robots.



Overlap

- Similar with the situation in assembly;
- Technologies related to human intervention decrease;
- Cloud computing is applied in Scenario 2 and 3.
- Overlap: wireless sensing, BIM, Virtual prototyping



Thanks and questions