# Resilience challenges in human-centric smart manufacturing

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Consiglio Nazionale delle Ricerche

# Multimodal Extreme Scale Data Analytics for Smart Cities Environments

MARVEL offers an Edge-to-Fog-to-Cloud (E2F2C) decentralised and scalable architectural solution capable of achieving fast and automatic recognition of environmental events based on real-time processing of large batches of audio and visual data.

Pilots:

- Trento: City monitoring
- Malta: Road traffic in cities
- Novi Sad: Crowd monitoring and security


More info:

This project has received funding from the European Union's Horizon 2020 Research and Innovation program under grant agreement No 957337.

# Motivation: Industry 4.0 requirements

Industrial applications demand different **requirements** that affect also **resilience**

Plattform Industrie 4.0:

latency/reliability/data rates are crucial

Example use cases:

- PLC ⇔ robot ⇔ **worker**: latency bound ~1ms, data rate <100 kb/s
- Camera ⇔ 3D system: 1-100 Mb per image with 5ms latency

| | Motion Control | Condition Monitoring | Augmented Reality |
|---|---|---|---|
| **Latency/Cycle Time** | 250µs – 1ms | 100ms | 10ms |
| **Reliability (fail rate)** | $1e^{-8}$ | $1e^{-5}$ | $1e^{-5}$ |
| **Data Rate** | kbit/s – Mbit/s | kbit/s | Mbit/s – Gbit/s |

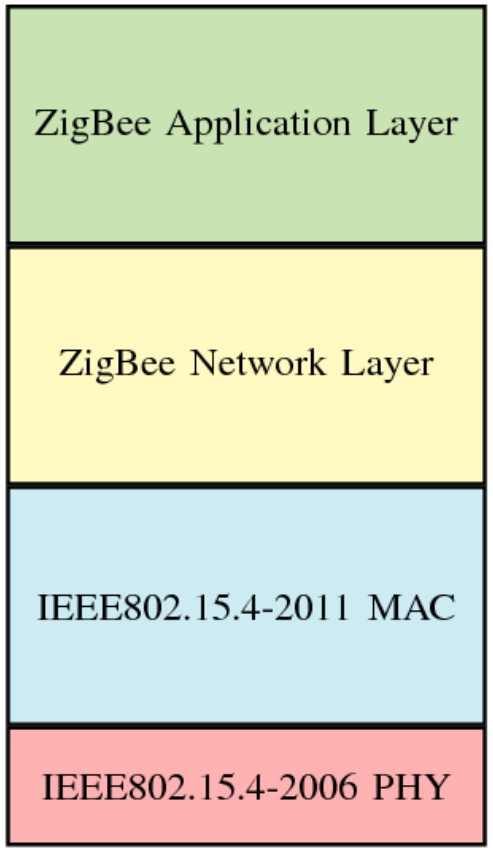
# Motivation: Industry 4.0 requirements

The requirements on managing the manufacturing network impose specific **constraints** on the **production process**

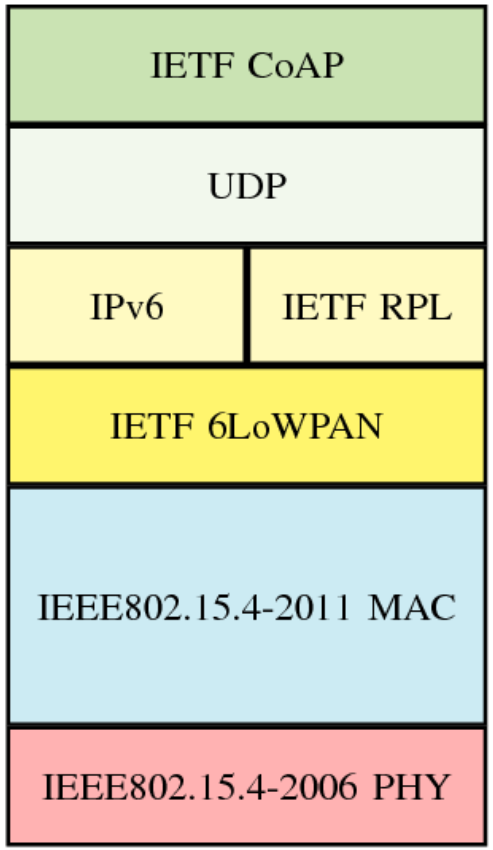
- High # of devices and battery life => limited rate per device
- High reliability => resilient data management schemes

| | Desired value | Application scenario |
|---|---|---|
| **Connectivity** | 300.000 devices per AP | Massive M2M connectivity |
| **Battery life** | > 10 years | Hard to reach deployments |
| **Reliability** | 99.999% | Protection and control |
| **Seamless connectivity** | - | Mobile devices |

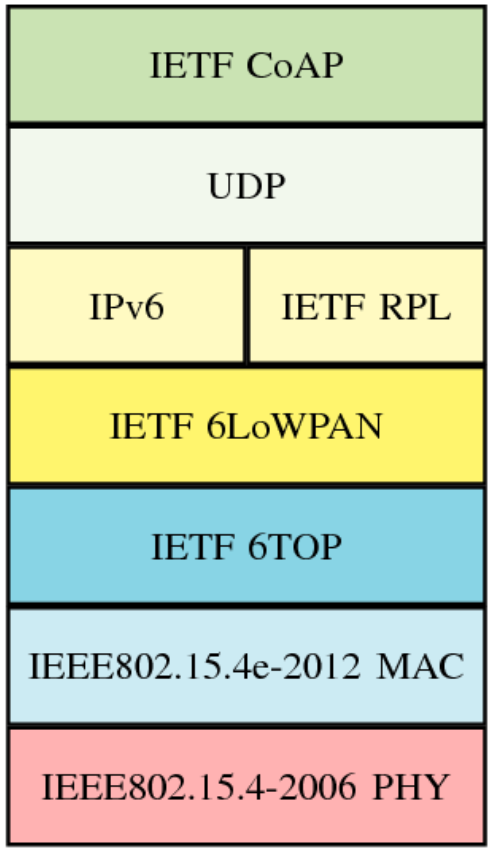
# Standardisation for stationary wireless networks




(a) ZigBee stack.



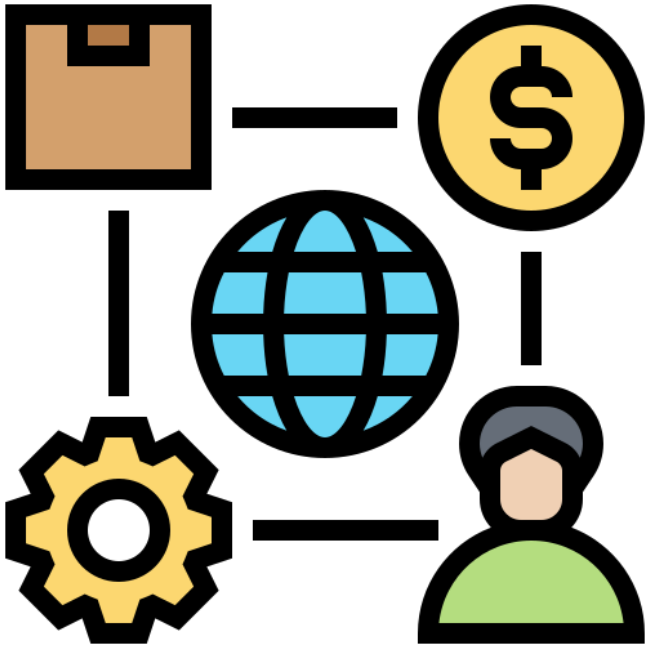

(b) ZigBeeIP stack.




(c) 6TiSCH stack.

**But what about human-centric settings?**

# Industry 5.0: More human-centric

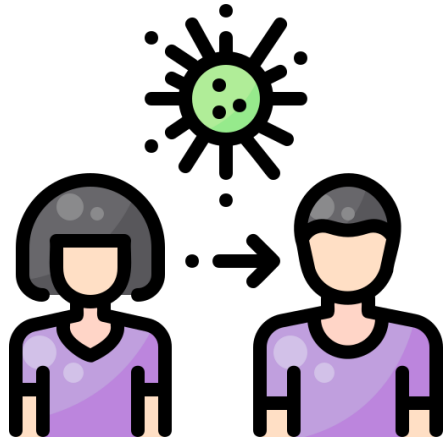


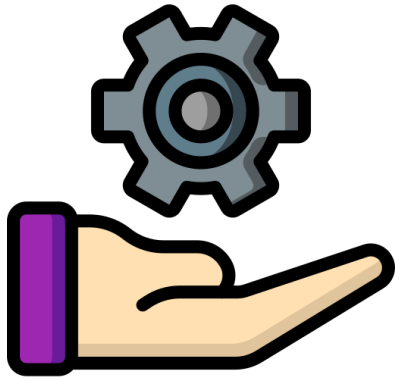
- Industry 5.0 provides a vision of industry that aims beyond **efficiency** and **productivity** as the sole goals, and reinforces the role and the contribution of industry to **society**.
- It places the **wellbeing of the worker** at the centre of the production process and uses new technologies to **provide prosperity** beyond jobs and growth while respecting the **production limits** of the planet.
- It complements the existing "Industry 4.0" approach by specifically putting research and innovation at the service of the transition to a sustainable, **human-centric** and **resilient** European industry.

# Post-pandemic manufacturing

According to McKinsey, the potential of Industry 4.0

- Is highlighted in the backdrop of the period characterised by the **critical** COVID-19 situation
- Manufacturing operators employing **automated and digital** means are **better positioned** to overcome the serious related consequences

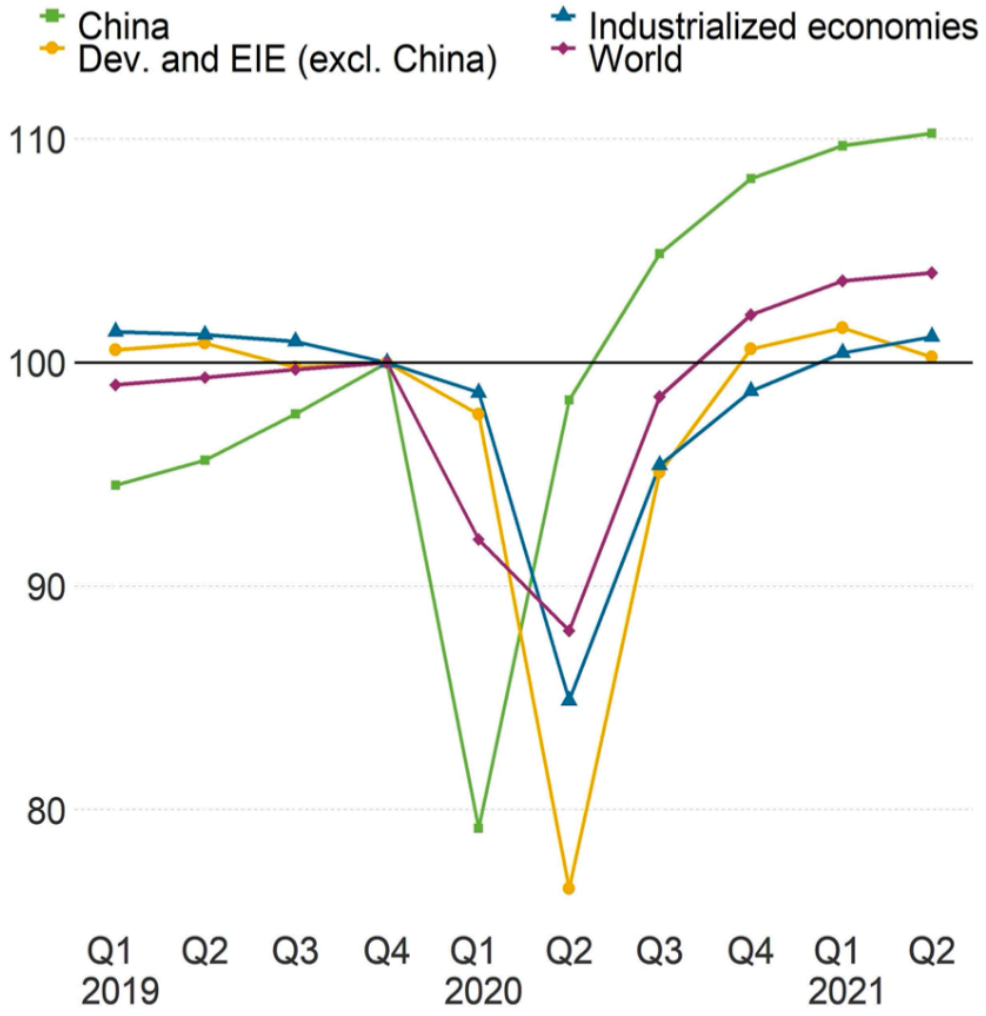




*Report available at:*

*M. Agrawal, et al, "Industry 4.0: Reimagining manufacturing operations after COVID-19," Article, McKinsey & Co, July 2020*

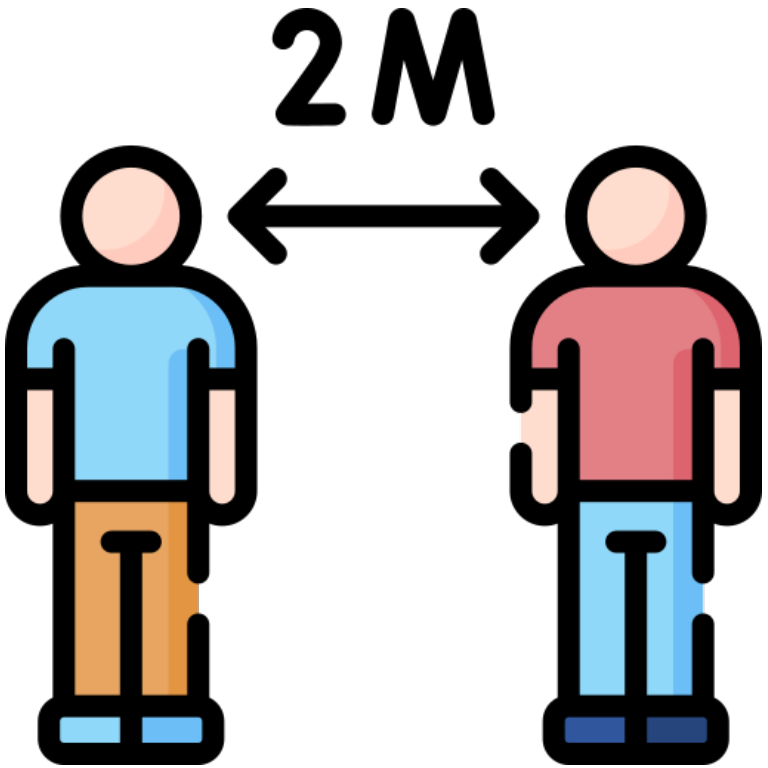
# Index of manufacturing production




According to UNIDO 2021 Q2 World Manufacturing report:

- The **drop** is shown to have been **unequal**; developing and emerging industrial economies did get affected more.
- The pace of **recovery** is also shown to be **unequal**; higher technology sectors have been recovering at a faster pace than lower technology sectors.
- The manufacturing **resilience has been at stake** worldwide.

# Will safe distancing help?




Application of non-pharmaceutical measures in order to **reduce** the **amount of physical contacts** and the distances among factory workers during an infectious disease outbreak.

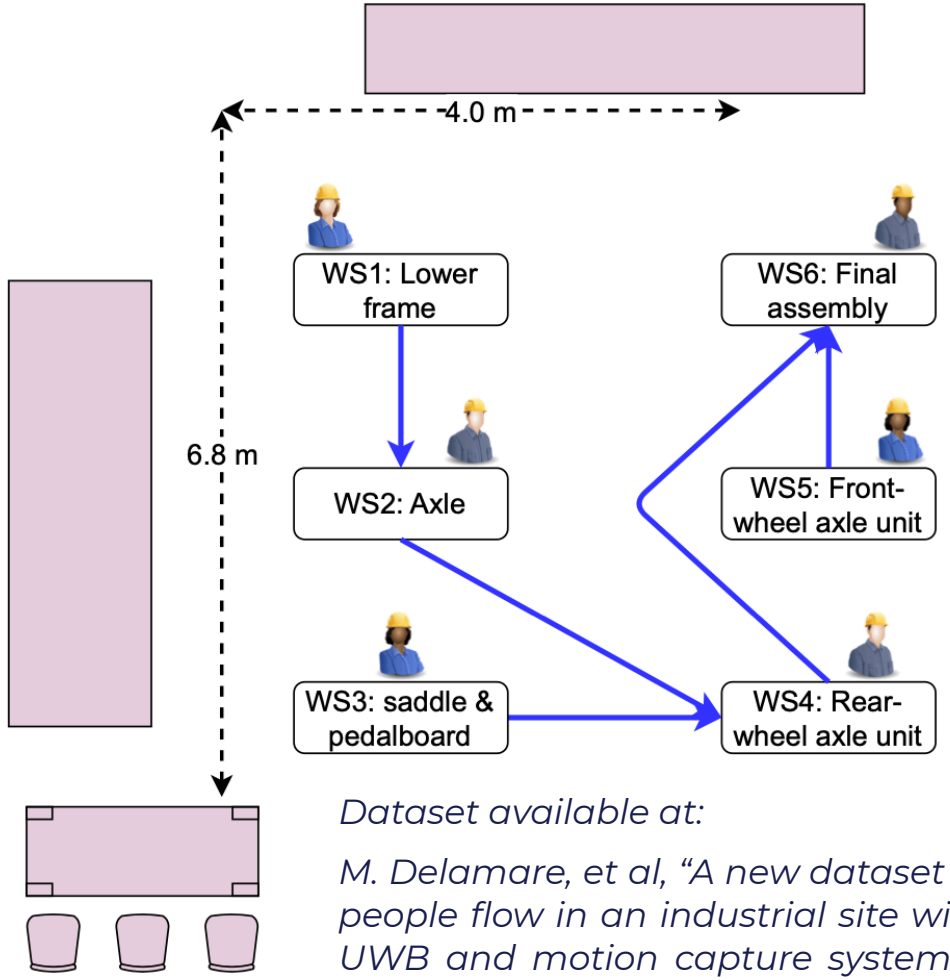
HOWEVER

Such measures can lead to **negative outcomes** on the **factory production efficiency**, as well as **privacy** and **personal liberty.**

They play an important role in locally **decreasing** the **impact** of viral outbreaks, by **reducing** the unsafe and unnecessary **interactions** among workers.

# A test case

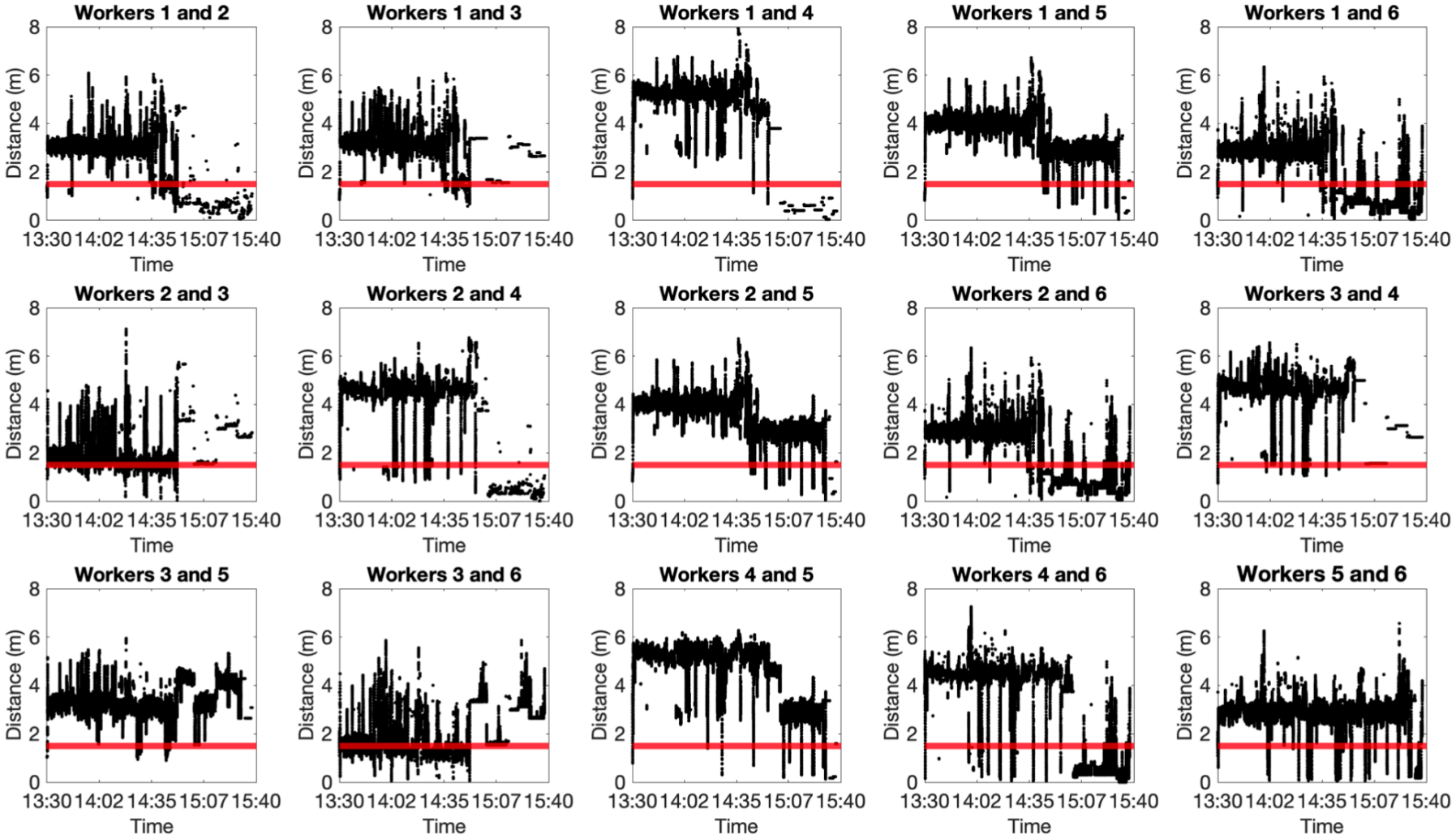
- Indoor **industrial worker** localisation dataset.
- **Manual assembly** line.
- Six tricycles in **three hours** by six workers.
- Each worker resides in one of the six **dedicated workstations** and performs her own part of assembly process.
- **Motion capture system** from Optitrack, with millimetre accuracy as a ground truth.




*Dataset available at:*

*M. Delamare, et al, "A new dataset of people flow in an industrial site with UWB and motion capture systems," Sensors, vol. 20, no. 16, p. 4511, 2020.*

# Why effective approaches are needed



# An emerging trade-off

A **customised adoption** of enabling technologies to address this trade-off might lead to two negative outcomes:

- significantly **sub-optimal production performance** due to much stricter safe distancing measures than required, and
- significantly **elevated risk of viral contagions** (and eventual sealing of facilities in case of viral outbursts) due to much looser safe distancing measures than required.

Last but not least, the **selection of the exact pervasive computing technologies** to be used for addressing the shop-floor requirements is not straightforward.

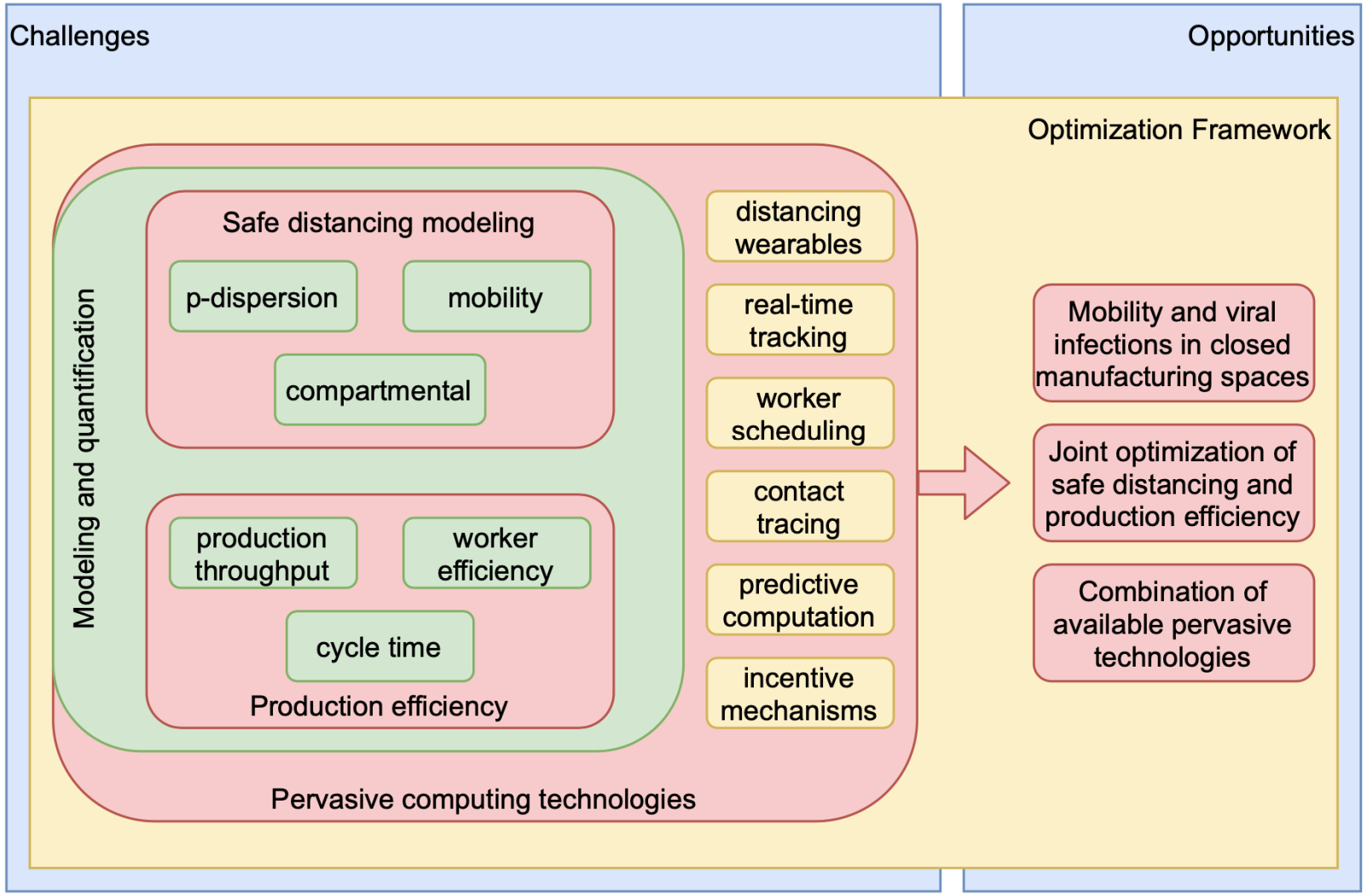
# Some fundamental questions

1. What is the formal **relation between safe distancing and production performance** in the shop-floor? Can we quantify both of them, model them, and explore their interplay under the prism of viral diseases like COVID- 19?

2. Which exact **combinations of pervasive computing technologies** can be beneficial for and can provide accurate implementation of safe distancing guidelines in closed shop-floor environments, using also **crowdsourcing techniques**?

3. Can we come up with a holistic, well-defined, accurate safe distancing **framework** which **optimises the production performance**, but at the same time **satisfies public health** (medical and government-imposed) **constraints**?

# Challenges and opportunities for resilience




**Exploit the "crowd wisdom"!**

*T. Raptis, et al.,"Pervasive Computing for Safe Distancing and Production Optimization in Manufacturing: Challenges and Opportunities," 3rd IEEE International Workshop on Smart Circular Economy (SmaCE), 2021*

# Challenge #1

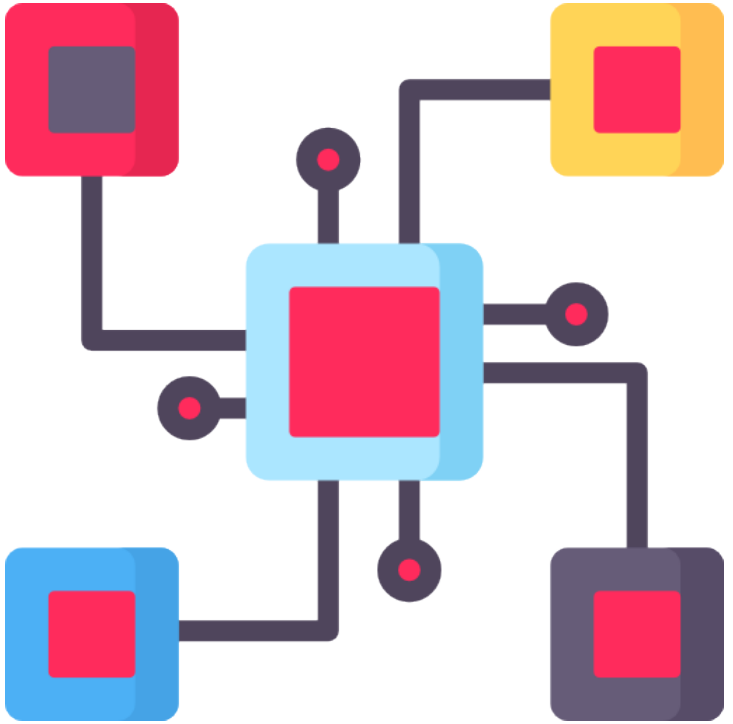
Extend dispersion problems beyond their static nature, in order to **capture and model the dynamics** of the closed manufacturing spaces with **mobile workers**. Exploit different mobility models (such as the population protocol model) or compartmental models for infectious diseases (such as the SEIR model).

# Challenge #2

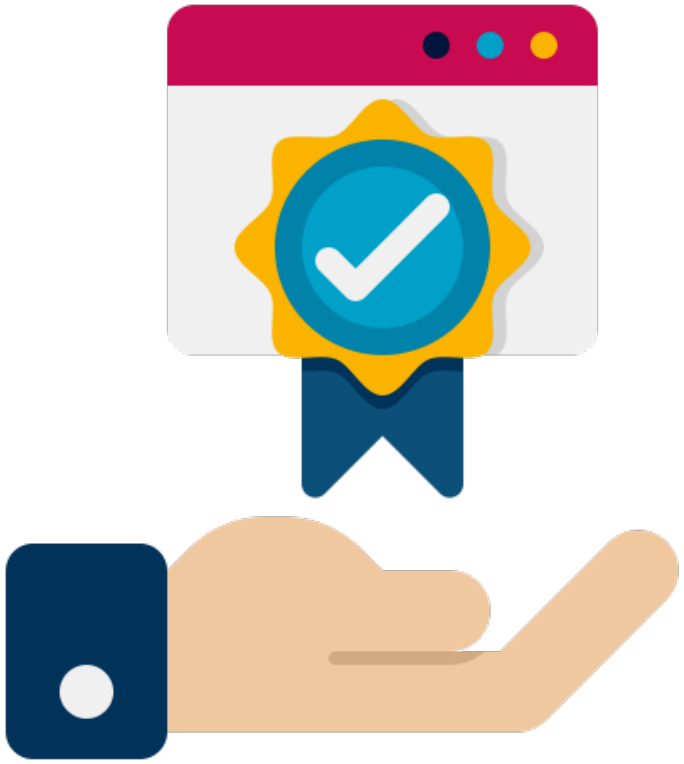

Design and define **appropriate production performance KPIs**, and at the same time align them to the **safe distancing modelling**, so as to be able to couple the two concepts into a joint optimization framework.

# Challenge #3

Fully grasp whether the **data coming from pervasive devices** can provide trustworthy information to the crisis management layers. Validate with combined medical and engineering expertise the devices usage in closed manufacturing spaces and shop-floors, especially when it comes to estimation **reliability**, **practicality**, and **data integration** capabilities.



# An opportunity?

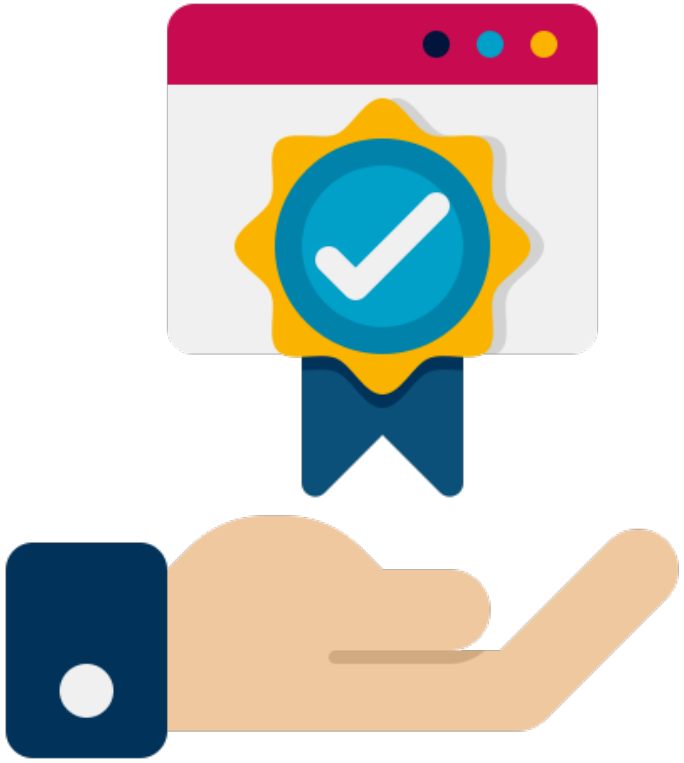


Although there are manufacturing KPI definitions, e.g.:

**ISO 22400-2:2014:** Automation systems and integration — Key performance indicators (KPIs) for manufacturing operations management — Part 2: Definitions and descriptions.

- Production time
- Starving time
- Queueing time
- Down time
- Scrap quantity
- Rework time
- Failure event
- etc.

# An opportunity?



**How about extending them to include the mobile crowd element**?

- **Align** the related standards/recommendations to the **emerging concepts** of Industry 5.0 and to the elements **human centric resilient** manufacturing.
- Take advantage of the wide variety of **pervasive computing technologies** that can be used in the shop-floor.
- Put emphasis **more on the ICT side** than on the manufacturing side for the new definitions.

# Thank you!
# Questions?

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