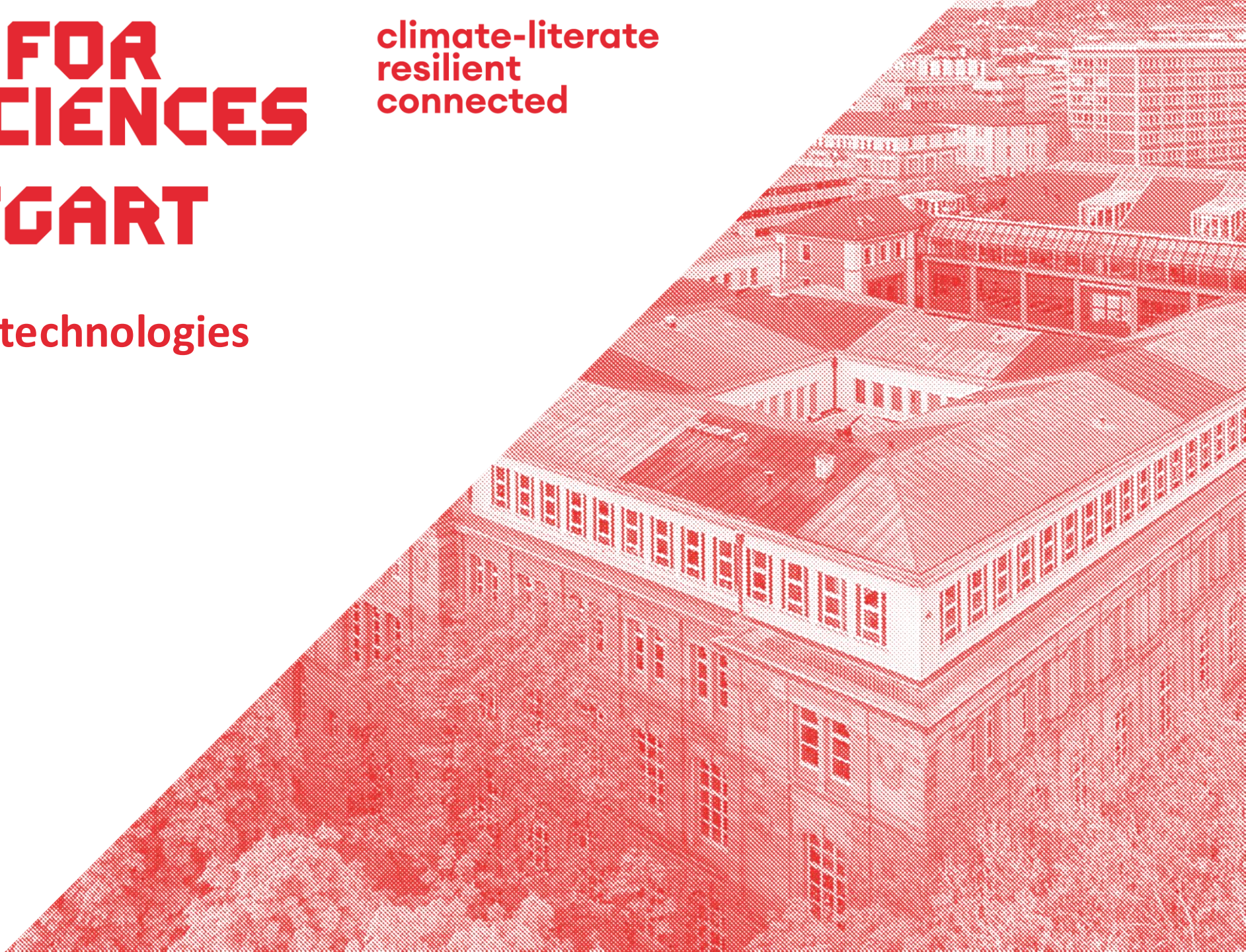


INSTITUTE FOR APPLIED SCIENCES HFT STUTTGART

climate-literate
resilient
connected

CitiVerse – emerging technologies
and interoperability

Prof. Dr.-Ing.
Dieter Uckelmann

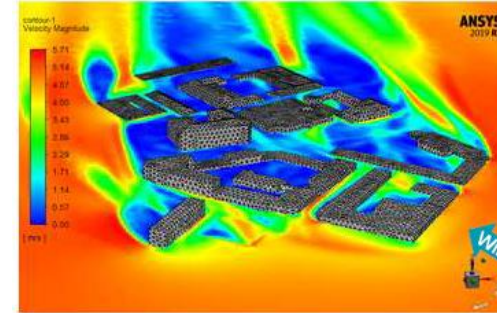




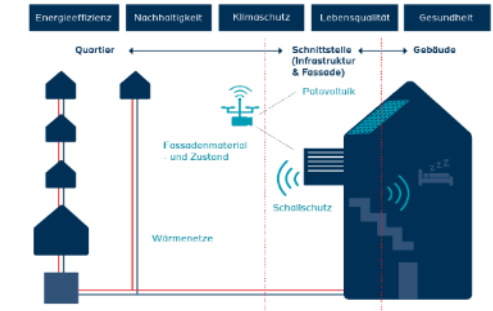
EMO4iCity
Emission-reduced mobility as part
of iCity



Streetmoves4iCity
Streetmoves for the intelligent city



SenSim4iCity
Sensors and simulation for energy
efficiency and the environment



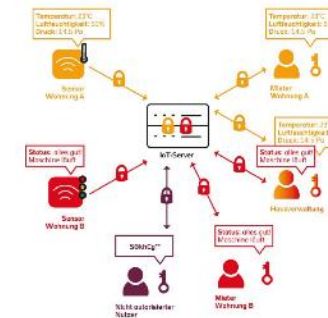
DiaOpt4iCity
DIAGnostics and OPTimisation of
building structures and heating
networks



UDiGit4iCity
Urban digital twins for the iCity



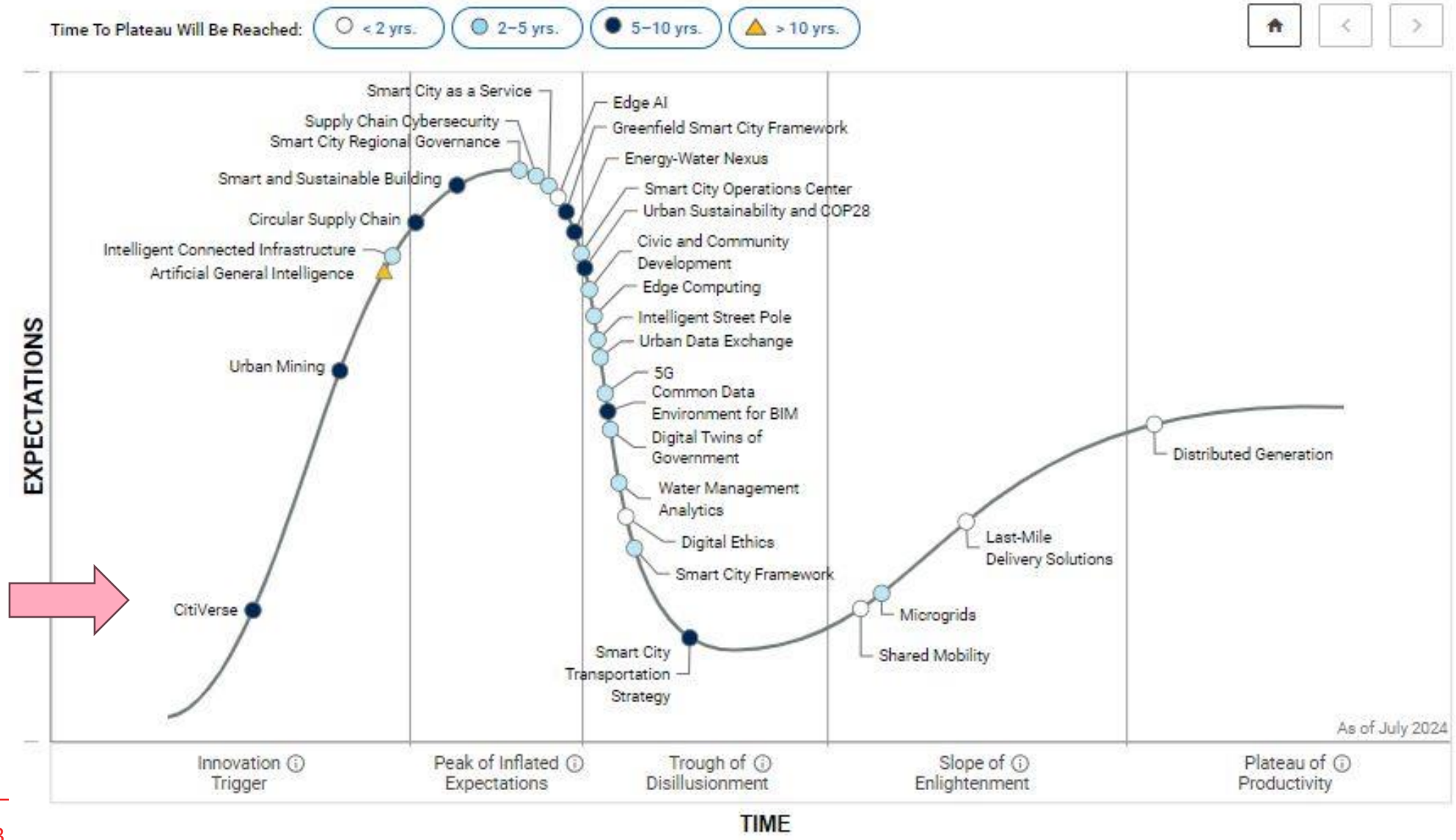
Sensoren4iCity
Network of autonomous sensors for
recording environmental data



Datasecurity4iCity
Data security measures for iCity data
flows

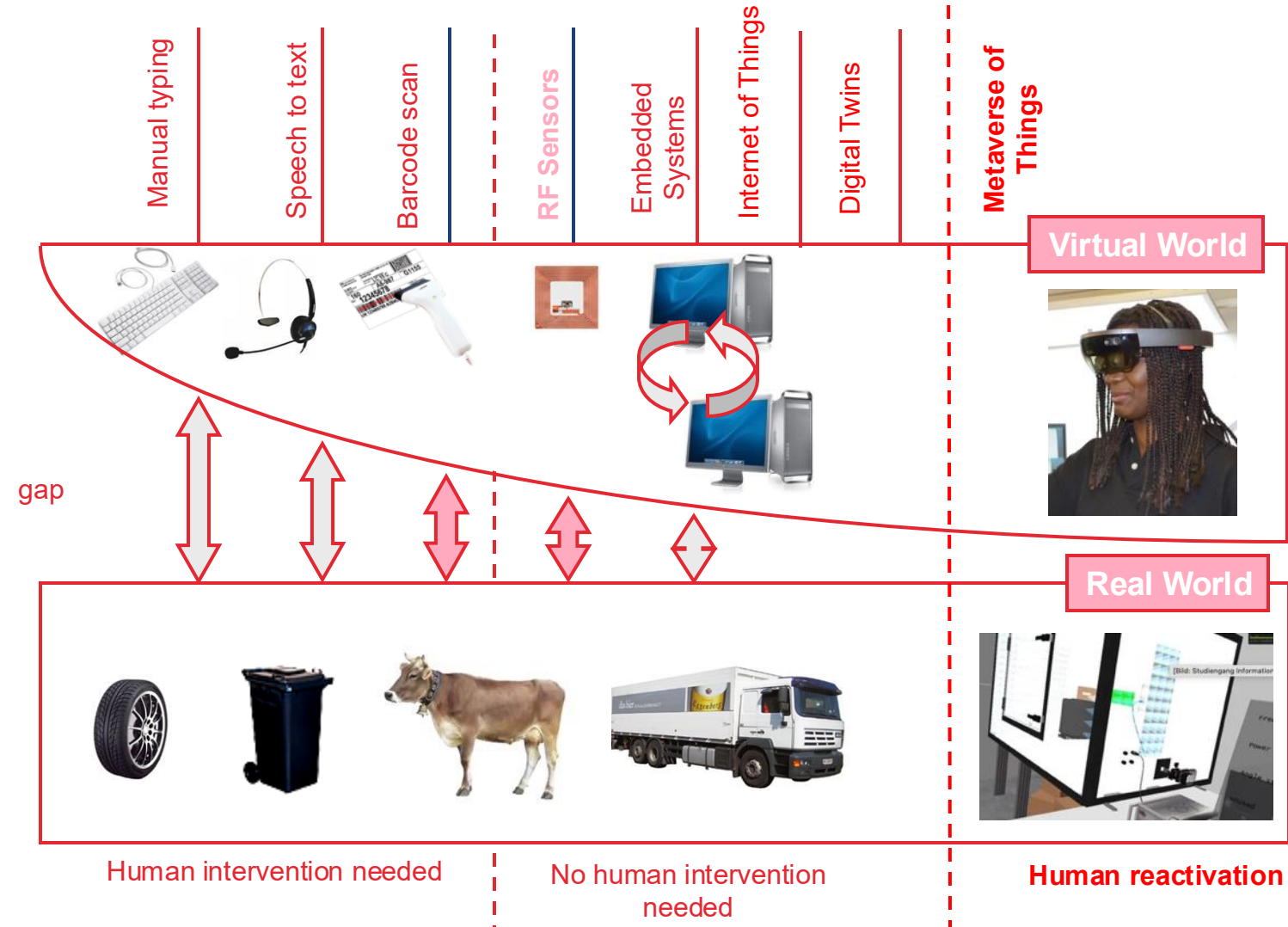


CampusLabor4iCity
Campus as a transdisciplinary
experiment



The goal: closing the gap between real and virtual worlds

Based on: Elgar Fleisch, Friedemann Mattern, Stephan Billinger (2003) Betriebswirtschaftliche Applikationen des **Ubiquitous Computing**: Beispiele, Bausteine und Nutzenpotentiale
<https://www.alexandria.unisg.ch/server/api/core/bitstreams/172b8eaf-679a-4886-98a2-e0bde3c0b2c2/content>



CitiVerse: Opportunities and Challenges (1)

Findings from literature and interviews

Topic	EDIC* Framework	Interoperability	Visual Urban Planning
Literature	- Multinational projects/EDIC bundle investments	- Open standards - Shared architecture - Knowledge transfer	- Better decision-making through visualization & simulation
Interviews	- Participation generally positive, but depends on funding & coordination	- Strong focus on development of standards & interoperable solutions - Breaking down data silos; closer collaboration between departments	- 3D simulation improves decision-making & participation
Agreement	High	High	High
Differences	- Interviews emphasize the following conditions: long-term staff, federal coordination	- Interviews add: access to sensitive data only for authorized users → shared use of base data	- No specific differences

*CitiVerse European Digital Infrastructure Consortium (EDIC)

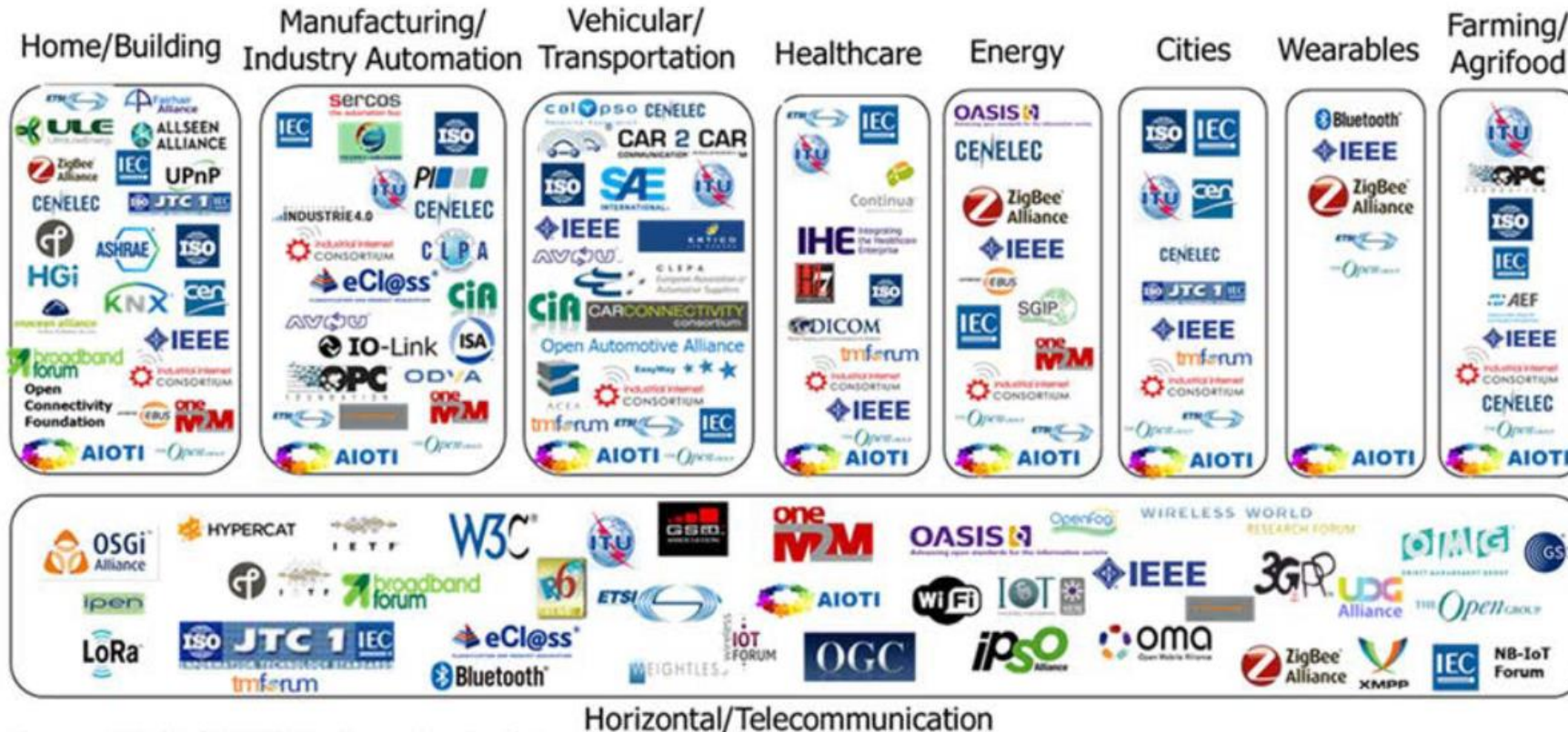
CitiVerse: Opportunities and Challenges (2)

Findings from literature and interviews

Topic	Immersive City Offerings (XR)	Efficiency & Cost Benefits	Digital Sovereignty
Literature	- XR/VR in education/culture/participation, but broad implementation still pending	- (Need for) concrete examples of savings	- Promotion of European values & companies, technology openness
Interviews	- Visualization & immersion increase acceptance among the population due to practical participation	- Large cities save through better planning and targeted resource use - Small cities benefit indirectly	- Open source approach as a sovereignty strategy
Agreement	High	Medium	High
Differences	- Interviews mention implemented applications	- Interviews differentiate benefits by city size and level of maturity	- Interviews specify open source in the local government context

Choosing the right approach, when there are >600 IoT initiatives and frameworks?

IoT SDOs and Alliances Landscape (Vertical and Horizontal Domains)



Source: AIOTI WG3 (IoT Standardisation) – Release 2.6

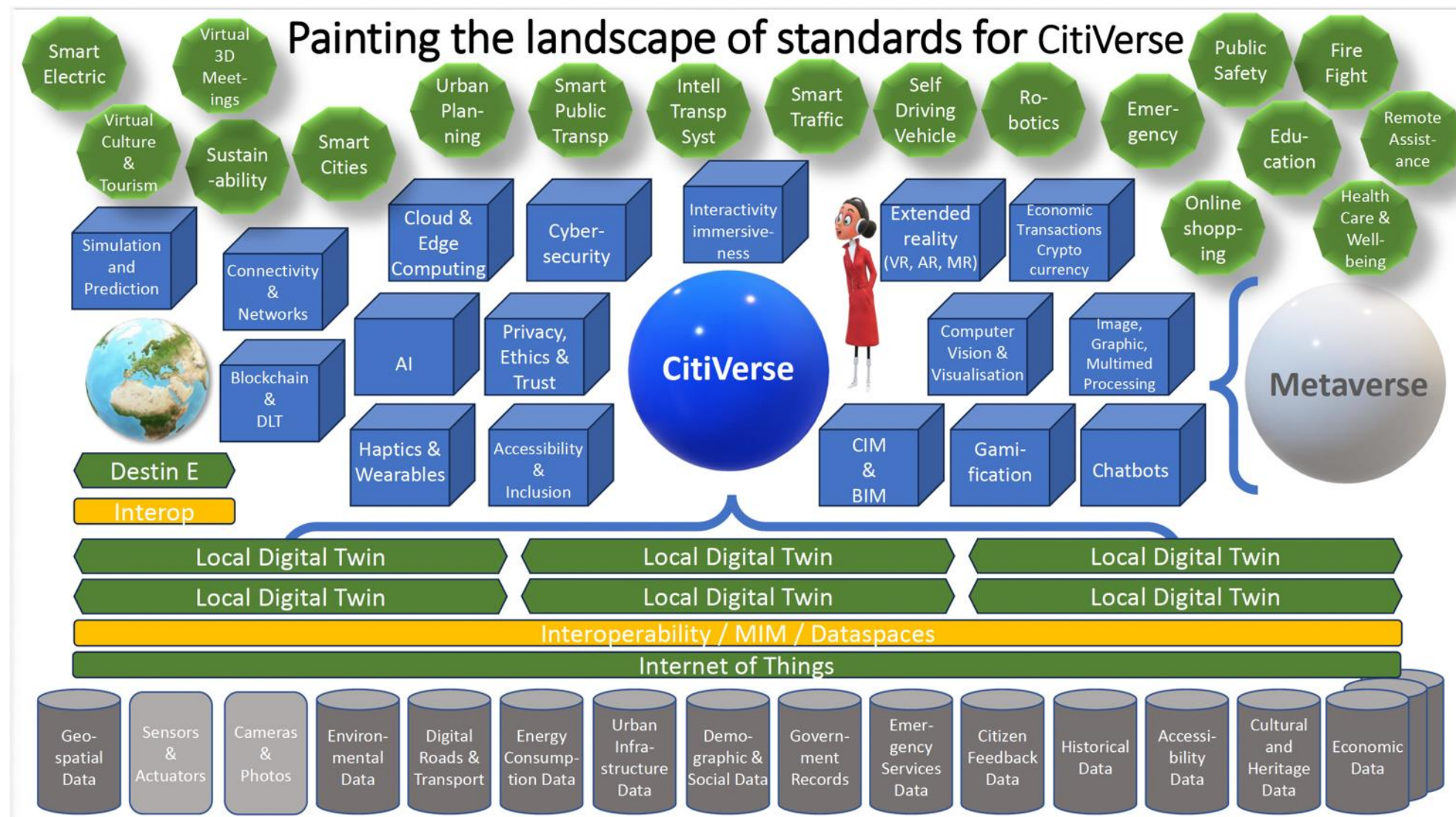
Source: ETSI TR 103 375 (2016)
SmartM2M; IoT Standards landscape and
future evolutions, https://aioti.eu/wp-content/uploads/2017/03/tr_103375v010101p-Standards-landscape-and-future-evolutions.pdf

Guidance on standards needed

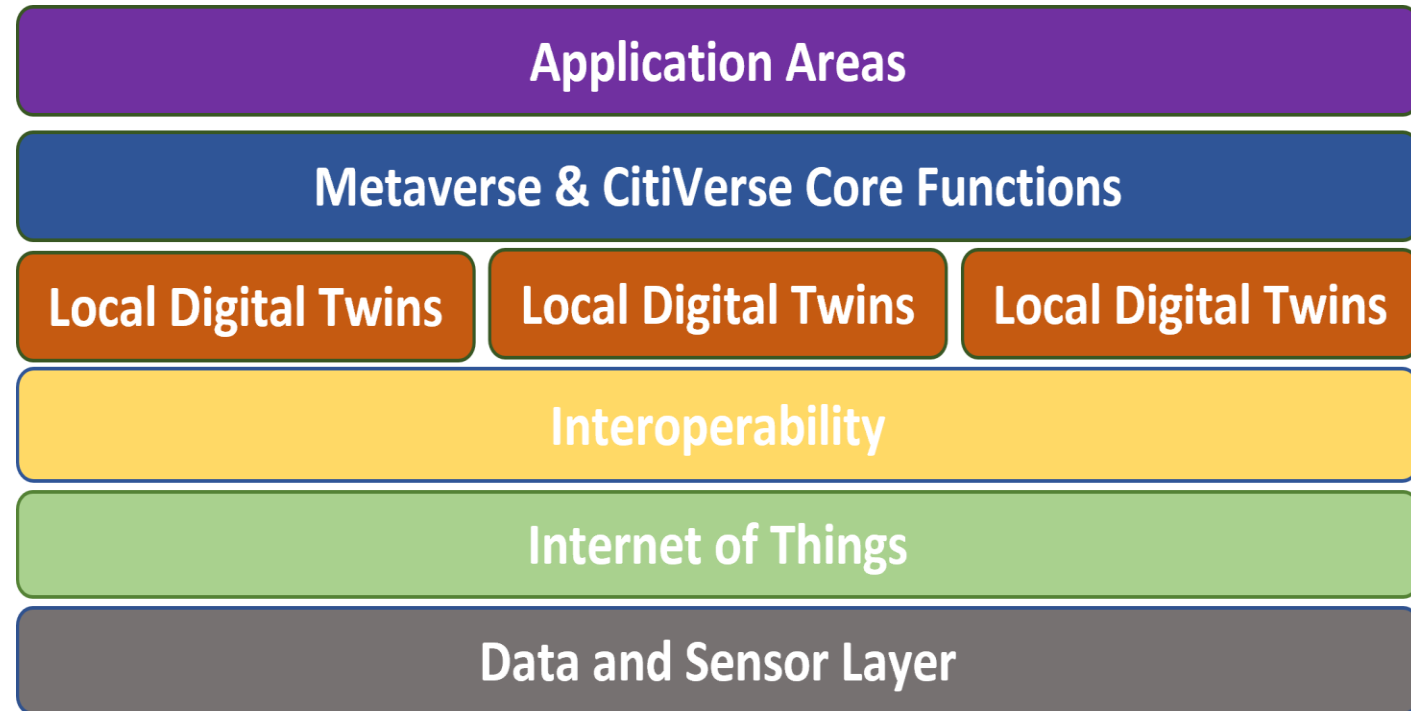
Discussion key-note: Uckelmann, D.
(2024) **Why providing a comprehensive IoT education is impossible – but we should nevertheless strive to do so.** Key-Note, International Conference on Smart Technologies & Education (STE2024). 6.-8.3.2024, Helsinki, Finland.

Remember: the original idea of the IoT was to have ONE! Internet of Things.

Do you know this landscape for CitiVerse standards?



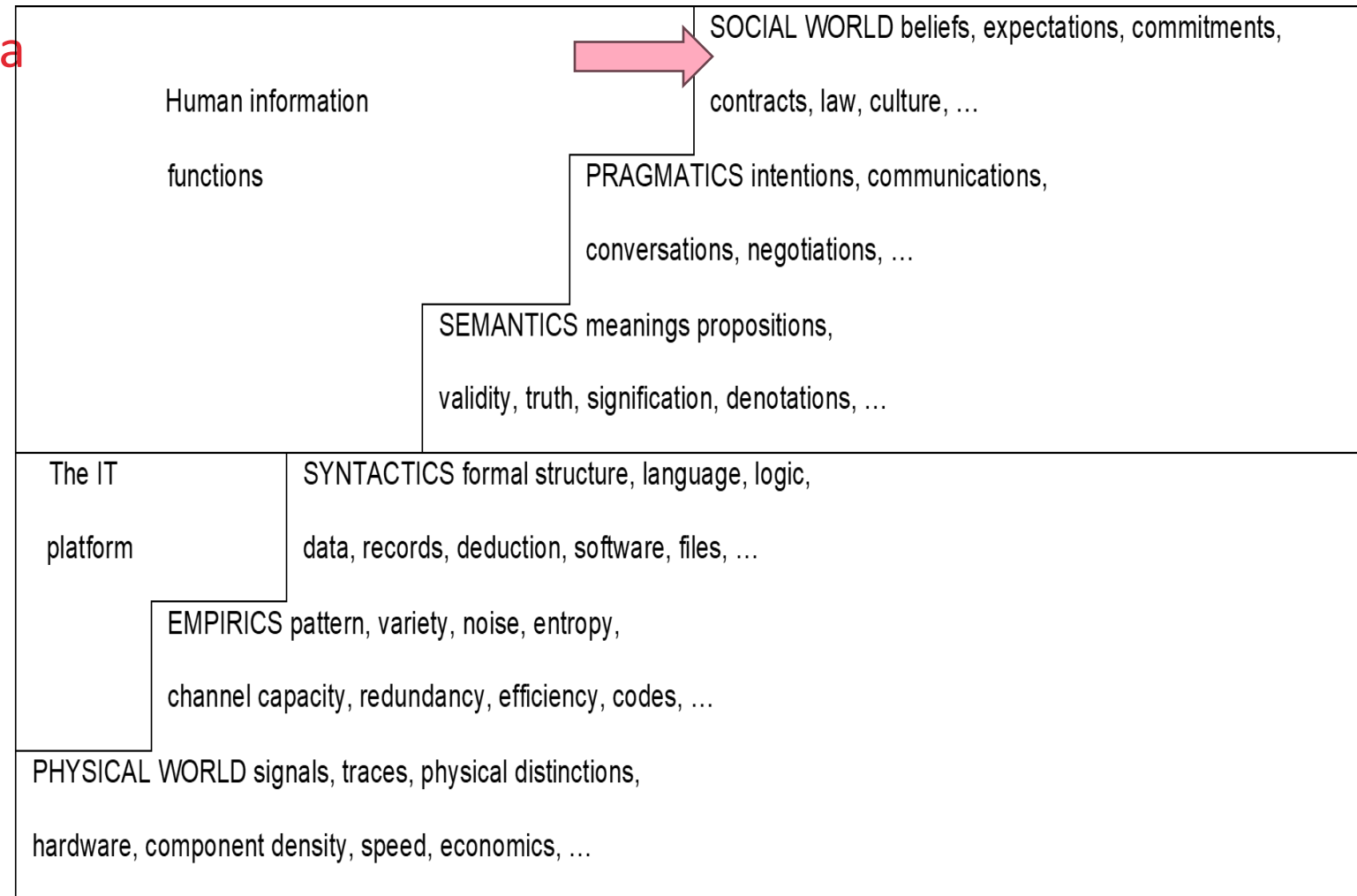
- Next-gen urban digitalization combining Smart Cities & Metaverse
- Multi-layered framework integrating IoT, Digital Twins, XR, AI
- Focus on immersive, interoperable, and participatory environments
- What's missing?



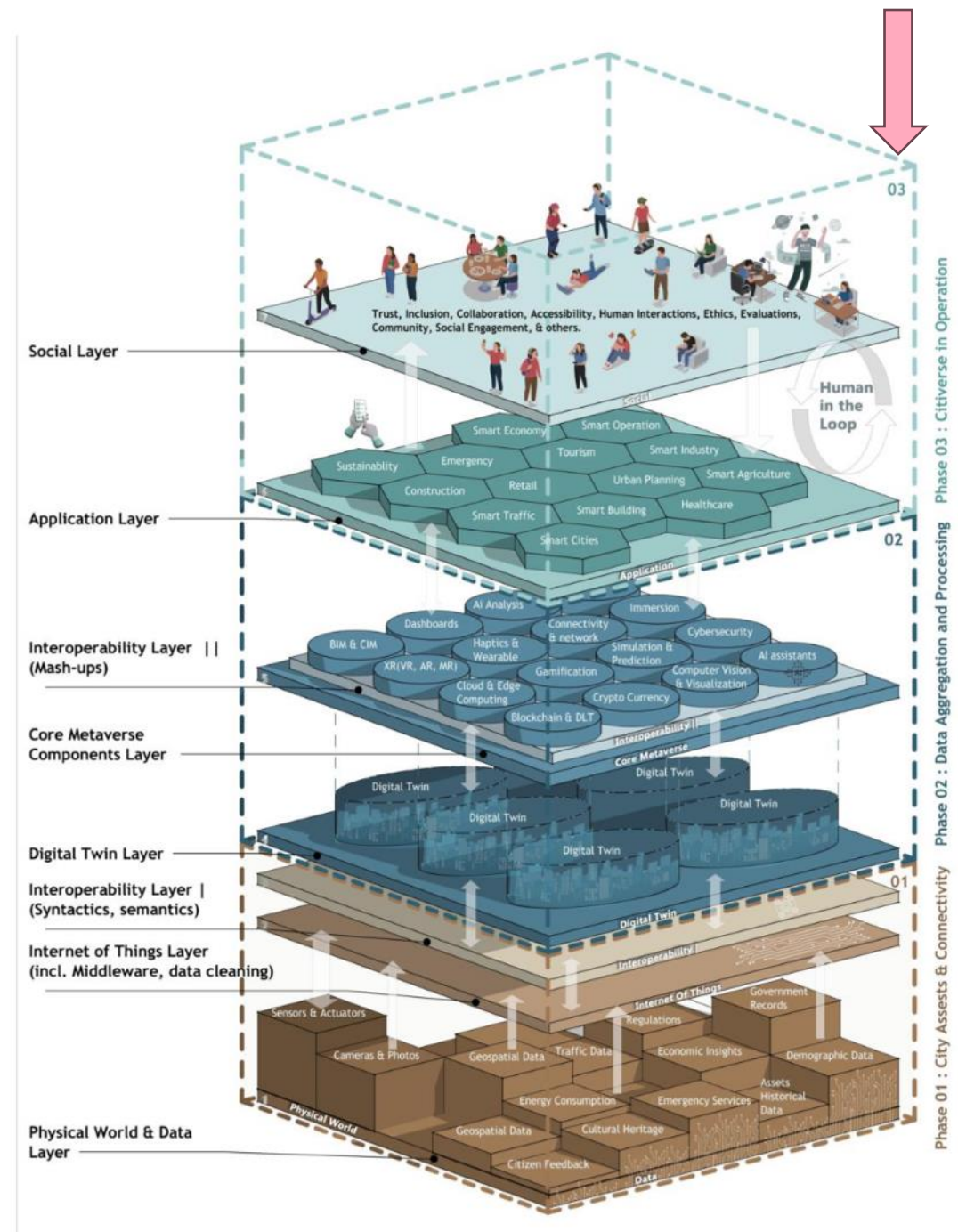
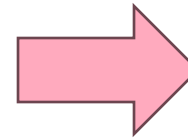
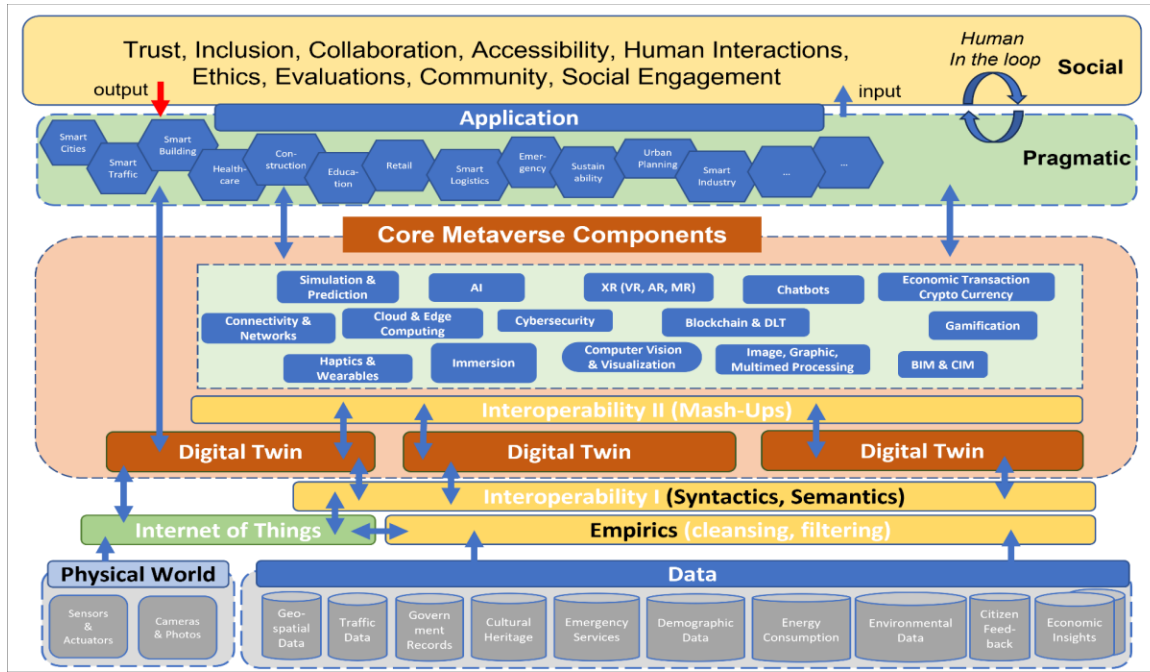
Traboulsi, S.; Uckelmann, D. (2025) CitiVerse: From Semiotic Theory to Interoperable, Human-Centered Smart Cities. 31st International Conference on Engineering, Technology and Innovation (ICE), Valencia. 16.-18.6.2025.

Simplified layered model based on StandICT (2023):
Standardisation Landscape for CitiVerse

Stamper's Semiotic Ladder serves as a benchmark for IT frameworks



Contribution to Track 7 paper on Global Digital CitiVerse Framework



Traboulsi, S.; Uckelmann, D. (2025) CitiVerse: From Semiotic Theory to Interoperable, Human-Centered Smart Cities. 31st International Conference on Engineering, Technology and Innovation (ICE), Valencia. 16.-18.6.2025.

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Mohamed Mohsen
Jun Li
Zhihan Lyu
Dieter Uckelmann

Global Digital Citiverse Framework

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Phase Number	Phase Name	Fundamental Question
1	City Assets and Connectivity	What physical assets, connectivity infrastructure, and data standards must be deployed across the city to enable real-time sensing and seamless data integration?
2	Data Aggregation and Processing Hubs	What data management infrastructure, processing capabilities, and analytical tools should be established to transform raw data into actionable intelligence?
3	Citiverse in Operation	What operational platforms, visualization tools, and governance mechanisms are required to monitor, manage, and optimize city functions in real-time?

Technical recommendations for each phase are listed in the document (f.e. pointing to ISO, ITU and other established standards)

13	Integrate AI/ML platforms for predictive analytics, anomaly detection, and automated decision support	When real-time data analysis, predictive modeling, and anomaly detection are required to optimize urban services and governance, anticipate incidents, and enable automated decision-making	ISO/IEC 5339 Artificial intelligence - Guidelines for AI applications
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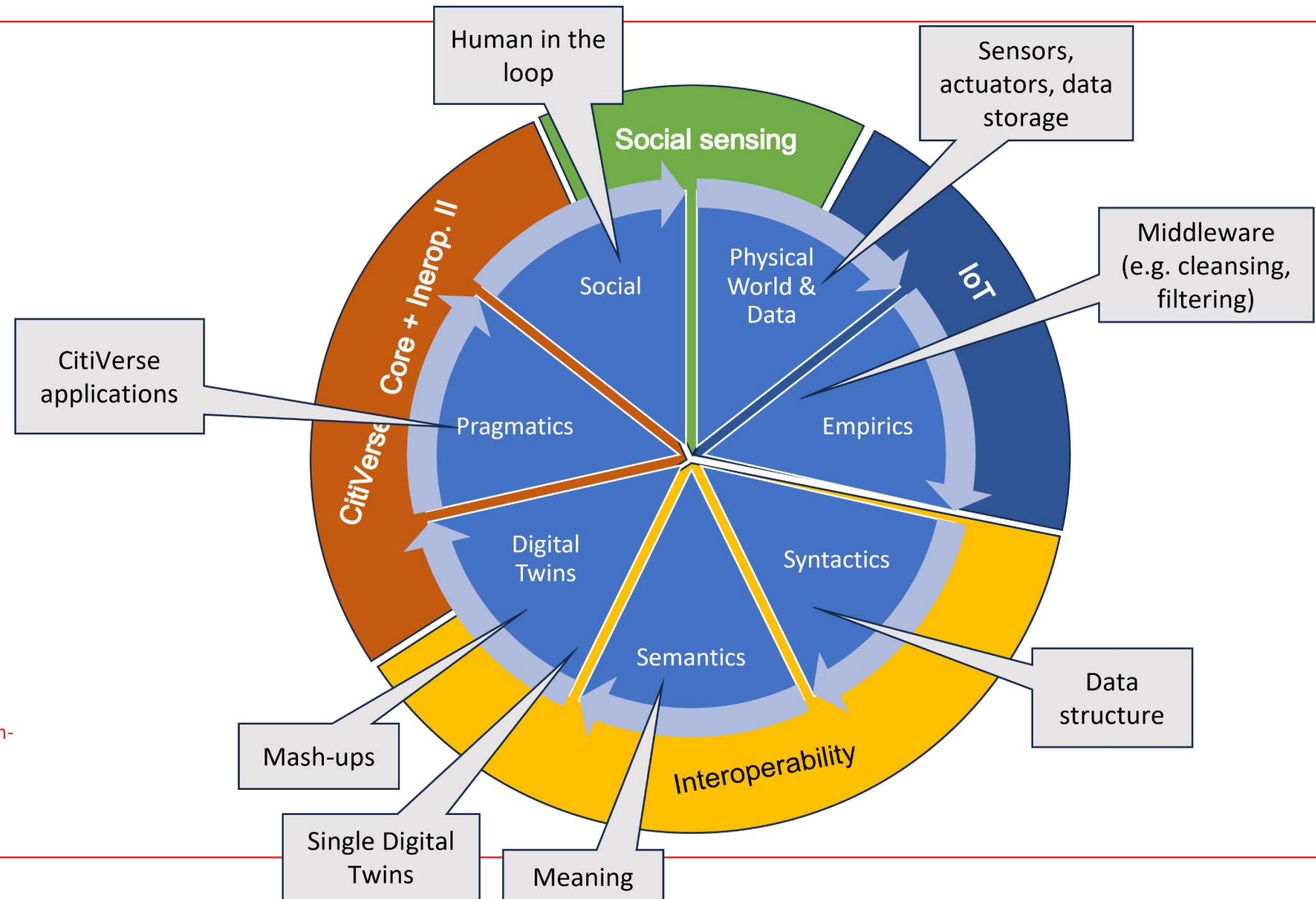
Suggestion 13: Integrate AI/ML platforms for predictive analytics, anomaly detection, and automated decision support

The integration of artificial intelligence (AI) and machine learning (ML) platforms into city operations and governance enables proactive and adaptive decision-making. Predictive analytics can anticipate traffic congestion, equipment failures, or energy demand spikes before they occur. Anomaly detection improves resilience by identifying irregular patterns such as water leakage, air quality deterioration, or cyber intrusions. Automated decision support then allows city managers to take timely action, reducing human error and improving service delivery⁴⁵.

One of the related standards is ISO/IEC 5339, which provides practical guidance for applying AI technologies across domains, focusing on governance, transparency, and implementation best practices. It is particularly relevant for ensuring that AI/ML platforms used for anomaly detection and predictive analytics in cities follow trustworthy and standardized approaches⁴⁶.

One of the related case studies is in Helsinki, Finland, where the city has applied AI-driven predictive analytics to optimize public transport operations. By analyzing passenger flows, weather conditions, and traffic patterns, the system forecasts demand and adjusts bus and tram schedules dynamically. This reduces congestion, improves service reliability, and enhances commuter satisfaction. The project highlights how AI/ML platforms, when responsibly integrated, can transform city operations by enabling proactive interventions rather than reactive responses⁴⁷.

Suggestion: an iterative Citiverse development model



Traboulsi, S.; Uckelmann, D. (2025) CitiVerse: From Semiotic Theory to Interoperable, Human-Centered Smart Cities. 31st International Conference on Engineering, Technology and Innovation (ICE), Valencia. 16.-18.6.2025.



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