TECHNICAL REPORT

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Internet of Everything (IoE) Taxonomy

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1) Context

The paradigm of the Internet of Everything (IoE) is a superset of the Internet of Things (IoT) [1] with connections among people, processes, data, and things. While IoT is concerned about things, IoE lays an upper foundation over IoT concept by connecting devices and people in one network [2], concerning intelligent network connections [3]–[6] and knowledge processes. These "intelligent services" compose the "everything" in IoE [7]. Figure 1 shows the "four pillars" of people, data, processes, and things in IoE.

IoE applications demand appropriate measures to be taken in the initial phases of its design and implementation [1]. Thus, there is a research gap regarding insights into IoE enablers' characteristics (people and things): (1) how they are combined and used as sensors and actuators in different application domains. Moreover, (2) how issues related to their capabilities and observations can affect the quality of intelligent services and knowledge creation.

To clarify this matter, we addressed the following research question: *How can IoE enablers be classified based on the knowledge they provide in intelligent tasks*?

And to answer this research issue, we conducted a systematic literature review of existing IoE and IoT taxonomies. From this, we were able to present a knowledge-based IoE taxonomy, according to the taxonomy development method by Nickerson et al. [8]. The proposed IoE taxonomy provides a consistent picture of IoE systems and their constituents (i.e., IoE sensors and actuators characterized in knowledge processes, observations, and network characteristics). We then validated the defined taxonomy with 50 IoE applications to prove its quality attributes and identify research challenges. A more detailed analysis of the systematic literature review was submitted to the Sensors Journal.

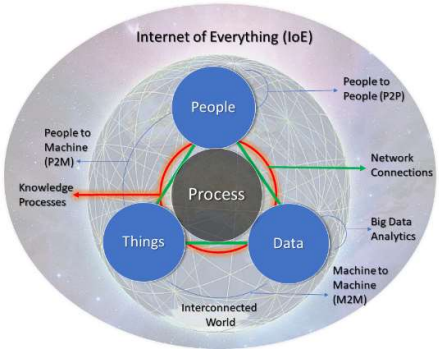

Figure 1. Internet of Everything, adapted from [9]

For this purpose, this Technical Report (TR) presents the IoE taxonomy (Figure 2) that identifies and categorizes sensors, attributes, and characteristics essential for developing IoE applications. The taxonomy dimensions and characteristics were derived from a theoretical foundation from the review of the related literature in IoE and IoT taxonomies. The proposed IoE taxonomy consists of four categories (*Knowledge, Type, Observation, Capabilities*), which groups 18 dimensions composed by mutually exclusive and collectively exhaustive characteristics:

(1) The *Knowledge* category relates to knowledge and information flow and contains five dimensions: Explicitness, Structure, Trust, Outcome, and Action.

(2) The *Type* category classifies sensors and actuators and contains five subcategories: Presentation, Nature, Use, Role, and Engagement.

(3) The *Observation* category relates to sensed context and contains five subcategories: Location, Reach, Mobility, Time, and Mode.

(4) The *Capabilities* category refers to the processing power and storage capacity of sensors and contains three subcategories: Communication, Processing, and Storage.

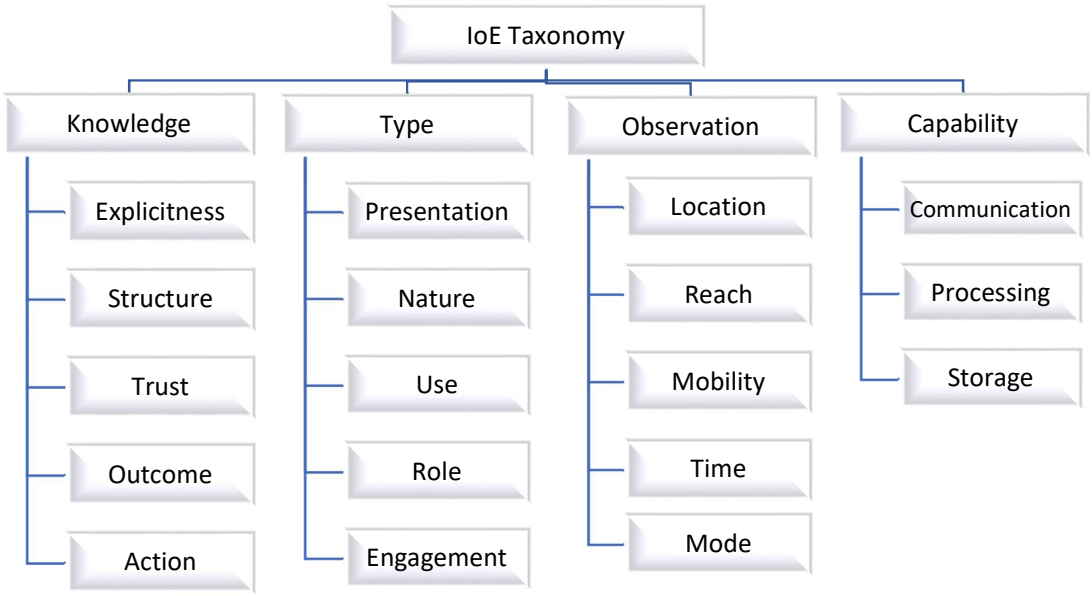

Figure 2. IoE Taxonomy

As demonstrated in Table 1, this TR validates the proposed IoE taxonomy with 50 IoE applications, in 3 different domains: Crowdsourcing applications [10], IoT/IoE applications with analytics [11], and Cyber-Physical Systems [12]. Our analysis will provide a roadmap for future research on IoE sensors and applications. The conceptual validations demonstrated that the proposed IoE taxonomy concerns qualitative attributes of being robust and comprehensive. It contains enough dimensions and characteristics to clearly distinguish and classify the objects of interest in distinct domains under consideration [8]. Table 1 provides an overview of 50 application analyses available as a dataset for future studies. (see Appendix for details of each application analyses):

a) **Crowdsourcing:** Considering the crowdsourcing application domain, we selected and analyzed 11 applications observed by **[10]** in a Crowd Application Database (http://cadb.demoro.net): Noisetube **[13]**, CenceMe **[14]**, MicroBlog **[15]**, Ubifit Garden **[16]**, GarbageWatch **[17]**, Galaxy Zoo **[18]**, eBird **[19]**, SenSay **[20]**, Jog Falls **[21]**, MobAsthma **[22]** e Transafe **[23]**.

b) **IoE applications with analytics:** Regarding IoE applications that benefit from data analytics, 30 applications were selected in Siow et al. **[11]** study that analyzed from 2011 to 2017 the top five application domains: health, living, environment, industry, transport. Each referred application domain has applications that support multiple analytical capabilities.

c) **Cyber-Physical Systems (CPS):** Concerning the domain of Cyber-Physical Systems (CPS) **[12]**, we validated the IoE taxonomy toward 9 CPS application domains **[12]**: health care industry, smart city infra control, smart home, environment observation, agriculture, manufacturing, energy and critical infrastructure, logistics and transport, security and safety.

Table 1. Validation of proposed IoE Taxonomy in distinct domains

Domain	**Application**	**Knowledge**					**Type**					**Observation**					**Capabilities**		
		Explicitness	Structure	Trust	Outcome	Action	Presentation	Nature	Use	Role	Engagement	Location	Reach	Mobility	Time	Mode	Communication	Processing	Storage
(1) Crowdsourcing applications [10]	Noisetube [13]	TEI	ST SS UN	UT	C S	AT/TR	PY CYP	HB/ EB/SB	WE EMB	S	O/P	FG	F	MO	PS	S/D/M P	4	E/C	CL
	MicroBlog [15]	TE	ST SS	UT	C	TR	PY CYP	HB EB	WE	S	P	FG	F	MO	PL	S	4	E/C	CL
	CenceMe [14]	TI	ST UN	UT	C	TR	PY CYP	HB EB SB	WE	S	O/P	FG	P	MO	PS	S/D	4	C	CL
	Ubifit Garden [16]	TI	ST SS	UT	C	AT/TR	PY CYP	HB SB	WE	S	O	FG	P	MO	PS	S D	3	E	CL/DL
	GarbageWatch [17]	E	ST	UT	C	TR	PY	HB EB	EMB SUR	S	P	CG	P	MO	PS	S	3	C	CL
	Galaxy Zoo [18]	TE	ST	UT	C	TR	PY CYP	HB SB	EMB SUR WE	S	P	CG	F	MO	PS	MP	4	C	CL
	eBird [19]	TE	ST	UT	C	TR	PY	HB EB	WE	S	P	FG	P	MO	PS	MP	3	C	CL
	SenSay [20]	E	ST	T	C	TR	PY CYP	EB	WE EMB	S	O	FG	P	MO	PS	S	2	E/C	DL/CL
	Jog Falls [21]	TEI	ST SS	T	C	AT TR	CY PY PHY	HB EB	WE SUR	S	P	FG	P	MO	PL	S D	4	E/C	DL/CL
	MobAsthma [22] e	TEI	ST SS	T	C	TR	PY CYP	HB EB SB	WE SUR	S	OP	FG	P	MO	PS	S D	4	C	CL

Domain	Application	Knowledge					Type					Observation					Capabilities		
		Explicitness	Structure	Trust	Outcome	Action	Presentation	Nature	Use	Role	Engagement	Location	Reach	Mobility	Time	Mode	Communication	Processing	Storage
	Transafe [23]	TEI	ST SS	UT	C	TR	PY CYP	HB SB	EMB	S	P	CG	P	MO	PL	S MP	4	C	CL
(2) IoT/IoE applications with analytics [11]	Neo-natal Care & AAL [24]	TEI	ST	T	C	TR	CY PY CYP	HB EB SB	WE SUR	S/A	O/P	FG	P	MO	PL	S D	4	C	CL
	AAL & Navigation [25]	I	ST UN	T	S/C	TR/AT	CYP	EB SB	SUR WE	S/A	O	CG	P	MO	PS	S D	4	C	CL
	Smart Clothing Monitoring [26]	EI	ST SS	T	C	TR	PY CYP	HB EB	WE SUR	S	P	FG	F	MO	PS	S	4	C	CL
	ECG Health Monitoring [27]	TE	ST SS	T	C	AU	PY CYP	HB EB	WE	S	OP	FG	P	MO	PL	SD	4	C	CL
	Prognosis [28]	TEI	ST	T	C/S	TR	PY CYP	HB EB	WE	S	P	FG	P	MO	PS	S D	4	C	CL NL
	Wellness Recommendations [29]	TEI	ST UN	T	S	TR	PY CYP	HB EB	WE SUR	S	OP	FG	P	MO	PL	S D	4	C	CL
	Traffic Control [30]	TI	ST UN	T	C	AT	CYP PY	EB SB	SUR EMB	S	O	CG	P	MO	PL	S D	3	C	CL
	Pedestrian & Car Detection [31]	TI	ST SSUN	T	C	TR	CYP	EB SB	SUR EMB	SA	O	CG	P	MO	PS	S D	3	C	CL DL
	Behaviour & Traffic Prediction [32]	TEI	ST UN	T	C	TR	PY CYP	HB EB	WE SUR	SA	P	CG	P	MO	PL	S D	3	C	CL DL

Domain	Application	Knowledge					Type					Observation						Capabilities		
		Explicitness	Structure	Trust	Outcome	Action	Presentation	Nature	Use	Role	Engagement	Location	Reach	Mobility	Time	Mode	Communication	Processing	Storage
	Travel Routing [33]	EI	ST SS UM	T	S	AT TR	PY CYP	EB	SUR EMB	S	O	CG	P	MO	PL	S D	3	C	CL NL
	Smart Parking [34]	I	ST UN	T	C	AT TR	PY CYP	EB	SUR EMB	SA	O	CG	P	MO	PS	S D	3	C	CL
	Parking Anomaly Detection [35]	I	ST UN	T	C	AT	PY CYP	EB	SUR EMB	SA	O	CG	P	MO	PS	S D	3	C	CL
	Cultural Behaviour [36]	TI	ST SS UN	T	C	TR	PY	EB	SUR	S	O	CG	F	MO	PS	S	3	C	CL
	Police Situational Awareness [37]	TEI	ST SS	T	C	TR	PY	EB	WE	S	P	CG	F	MO	PS	S MP	3	C	CL DL
	Public Safety Monitoring [38]	TEI	ST SS	T	C	AT	PY CYP	HB EB	SUR EMB	S	O	CG	F	MO	PS	S D	3	C	CL
	Smart Building Heating [39]	EI	ST	T	C	AT	PY CYP	EB	EMB SUR	SA	O	CG	F	MO	PS	S D	3	C	CL
	Memory Augmentation [40]	I	ST SS	T	S	TR	PY CYP	HB EB	WE SUR	SA	P	CG	F	MO	PS	S D	4	C	CL
	Wearable Lifestyle Monitor [41]	TI	ST SS	T	C	TR	PY CY	EB SB	WE SUR	S	O	FG	P	MO	PS	S D	3	C	CL
	Disaster Detection & Warning[42]	I	ST UN	T	C	TR	CYP PY	EB HB	SUR WE	S	P	FG	P	MO	PS	SD	4	C	CL
	Urban Disaster Storytelling [43]	I	ST SS UN	T	C	TR	PY CYP	HB EB	WE SUR	S	P	CG	P	MO	PS	S	4	C	CL

Domain	Application	Knowledge					Type					Observation					Capabilities		
		Explicitness	Structure	Trust	Outcome	Action	Presentation	Nature	Use	Role	Engagement	Location	Reach	Mobility	Time	Mode	Communication	Processing	Storage
	Wind Forecasting [41]	EI	ST SS	T	C	TR	PY CYP	EB	EMB SUR	S	P	CG	P	MO	PS	S	4	C	CL
	Energy Usage Recommendations [44]	I	ST UN	T	S	AT	PY CYP	EB	EMB SUR	S	O	FG	P	MO	PS	S	4	C	CL
	Energy Policy Planning [45]	I	ST	T	C	TR AT	PY	EB	EMB SUR	SA	O	FG	P	MO	PS	S	4	C	CL DL
	Smart Energy System [46]	EI	ST SS	T	C	AT	PY CYP	EB	SUR	SA	O	FG	P	FX	PS	S D	4	C	CL NL
	On Shelf Availability [47]	TEI	ST SS UN	T	S	AT	PY CYP	EB HB	WE SUR	S	P	FG	P	FX	PS	S	4	C	CL NL
	SCM Environ. Control [48]	I	ST UN	T	S	AT	PY	EB	EMB SUR	SA	O	FG	P	FX	PS	D MP	4	FC	CL
	SCM 4PL [49]	TEI	ST	T	C	AT	CY	EB	EMB	SA	P	FG	P	FX	PL	S D	4	C	CL
	Floricultural SCM [50]	TEI	ST SS	T	S	TR	CY PY	HB EB	SUR	SA	P	FG	P	MO	PL	S D	4	C	CL
	Smart Farming [51]	TEI	ST SS	T	S	TR	CY PY	HB EB SB	SUR EMB	SA	OP	FG	P	MO	PS	S D	4	C	CL
	Chemical Process Monitoring [52]	EI	ST UN	T	C	AT	PY CYP	SB EB	SUR EMB	SA	P	FG	P	MO	PL	S	4	C	CL DL

Domain	**Application**	**Knowledge**					**Type**					**Observation**					**Capabilities**		
		Explicitness	Structure	Trust	Outcome	Action	Presentation	Nature	Use	Role	Engagement	Location	Reach	Mobility	Time	Mode	Communication	Processing	Storage
(5) Cyber-Physical Systems	health care industry [12]	TEI	ST UN	T	C	TR AT	CY PY	HB EB	SUR EMB	S	O	FG	P	MO	PL	S	5	C	CL
	smart city infra control [12]	EI	ST UN	T	C	AT	CY PY	SB EB	SUR	SA	O	FG	F	MO	PS	S D	4	C	CL
	Smart home [12]	EI	ST SS	T	C	AT TR	PY	SB EB	SUR EMB	SA	O	FG	P	MO	PS	S D	4	C	CL
	Environment Observation [12]	EI	ST SS	T	S	AT	PY	SB EB	SUR	SA	O	FG	F	MO	PS	S D	4	C	CL
	Agriculture [12]	EI	ST	T	C/S	AT	PY	SB EB	SUR EMB	SA	O	FG	P	MO	PS	S D	4	C	CL
	Manufacturing [12]	EI	ST	T	C/S	TR	PY CYP	SB EB	SUR EMB	SA	O	FG	P	MO	PS	S	4	C	CL
	Energy and Critical Infrastructure[12]	EI	ST SS	T	S	AT TR	PY	SB EB	SUR EMB	SA	O	FG	P	MO	PS	S	4	C	CL
	Logistics and Transport: [12]	EI	ST SS	T	S	AT TR	PY	SB EB	SUR EMB	SA	O	FG	P	MO	PS	S	4	C	CL
	Security and Safety: [12]	EI	ST SS	T	S	AT TR	PY	SE EB	SUR EMB	SA	O	FG	P	MO	PS	D	5	C	CL

Dimensions	Legend
Explicitness	T– Tacit / E – Explicit / I – Implicit
Structure	ST – structured / SS – Semi-structured / UN – Unstructured
Trust	T – Trustful / UT – Untrustful
Outcome	C – Complements / S – Substitutes
Action	AT – Automation / TR – Transformation
Presentation	CY – Cyber / PY – Physical / CYP – Cyber-Physical
Nature	EB – Electronic-based / SB – Software-based / HB – Human-based / NHB – Non-Human-based
Use	WE – Wearables / SUR – Surroundable / EMB – Embeddable
Role	S – Sensor / AC – Actuator / SA – Sensor and actuator
Engagement	O – Opportunistic / P – Participatory
Location	CG - Coarse-grained / FG – fine-grained
Reach	F – Full / P – Partial
Mobility	FX – Fixed / MO – Mobile
Time	PL – Pull / PS – Push
Mode	S – Sense / D – Derive / MP – Manually Provided
Communication	0 -No connection / 1 - Technical / 2 - Syntactical / 3 - Semantic/ 4 - Pragmatic / 5 - Conceptual
Processing	Edge computing (EC) / fog computing (FC) / Cloud computing (C)
Storage	DL – Device level / NL – Network level /CL – Cluster level

Appendix

Category /Dimension		Characteristic of NoiseTube [13]
Knowledge	Explicitness	**Tacit**: user personal annotation ǀ **Explicit**: geo-localised measurements ǀ **Implicit**: real-time signal processing algorithm
	Structure	**Structured**: measured data **Semi-structured**: tags entered by participants ǀ **Unstructured** real-time noise exposure data
	Trust	**Trustful**: (expert/scientist) as filters or regulators ǀ **Untrustful**: any user own contributions
	Outcome	**Complements**: assessment of noise pollution ǀ **Substitutes**: awareness of and insight into the problem of urban noise pollution
	Action	**Automation** participative noise pollution monitoring: ǀ **Transformation**: potential links with epidemiological studies at a larger scale.
Type	Presentation	**Cyber**: mobile sensing application ǀ **Physical**: citizens ǀ **Cyber-Physical:** mobile phones
	Nature	**Electronic based**: mobile phones **Software-based**: signal processing algorithm **Human-based**: citizens ǀ **Non-Human-based**: --
	Use	**Wearables**: mobile phones ǀ **Surroundable**s: ǀ **Embeddables**: GPS, microfones
	Role	**Sensor**: GPS-equipped mobile phones , citizens ǀ **Actuator**:
	Engagement	**Opportunistic**: a tool to self-monitor one's individual exposure ǀ **Participatory**: people-centric data collection
Observation	Location	**Coarse-grained**: high granularity ǀ **Fine-grained**: evidence of harmful noise exposure levels
	Reach	**Full**: urban public spaces **Partial**: personal people centric
	Mobility	**Fixed**: -- ǀ **Mobile**: mobile phones
	Time	**Pull**: -- ǀ **Push** local information from different sensors (noise, GPS coordinates, time, user input):
	Mode	**Sense**: measured data ǀ **Derive**: real-time noise exposure data ǀ **Manually provided**: user personal annotation
Capabilities	Communication	**Pragmatic communication** wireless sensor networks (WSN)
	Processing	**Cloud**: Google Maps and Google Earth ǀ **Fog/Edge**: mobile application was written in Java ǀ **Mobile cloud**:
	Storage	**Device-level**: ǀ **Network level** ǀ **Cluster level** MySQL, Google Earth:

Category /Dimension		Characteristic of MicroBlog [15]
Knowledge	Explicitness	**Tacit**: user blogs, Human responses to user queries **Explicit**: time and location of the device, responses stored in a database ǀ **Implicit**:
	Structure	**Structured**: Sensor data, including location, WiFi SSIDs, GSM tower IDs, and signal strengths, **Semi-structured**: multimedia blogs ǀ **Unstructured**:
	Trust	**Trustful**: ǀ **Untrustful**: potential security concerns need to be addressed.
	Outcome	**Complements**: microblogs superimposed on virtual space (Internet maps) ǀ **Substitutes**:
	Action	**Automation**: ǀ **Transformation**: allows smartphone-equipped users to generate and share geo-tagged multimedia called microblogs
Type	Presentation	**Cyber**: ǀ **Physical**: users ǀ **Cyber-Physical**: Nokia N95 mobile phones
	Nature	**Electronic-based**: Nokia N95 mobile phones, accelerometer vibrations, health sensors, WiFi SSIDs **Human-based**: users ǀ
	Use	**Wearables**: Nokia N95 mobile phones ǀ **Surroundable**s: ǀ **Embeddables**:
	Role	**Sensor**: Nokia N95 mobile phones, users ǀ **Actuator**:
	Engagement	**Opportunistic**: ǀ **Participatory**: people-centric data collection
Observation	Location	**Coarse-grained**: ǀ **Fine-grained**: microblogs are positioned on a spatial platform, such as Google Maps
	Reach	**Full**: A variety of web services can be used to mine, group, and correlate blogs based on interest themes, and social networks.
	Mobility	**Fixed**: ǀ **Mobile**: mobile phones
	Time	**Pull**: Location coordinates are periodically uploaded to the server, along with requests for new queries. ǀ **Push**: phone automatically sense and dispatch events
	Mode	**Sense**: Data from phones is received at a Micro-Blog application server ǀ **Derive**: ǀ **Manually provided**:
Capabilities	Communication	wireless network such as WiFi or cellular, **Pragmatic communication** **Conceptual communication**
	Processing	**Cloud**: server C++, PHP, Ajax,and MySQL ǀ **Fog/Edge**: Micro-Blog phone client ǀ **Mobile cloud**:
	Storage	**Device-level**: ǀ **Network level** ǀ **Cluster level**: MySQL

Category /Dimension		Characteristic of CenceMe [14],
Knowledge	Explicitness	**Tacit**: customized tagis any form of activity, gesture, or classified audio primitive that the user can bind to a personal meaning **Explicit**: ׀ **Implicit**: CenceMe classifiers running on the phone and the backend
	Structure	**Structured**: **Semi-structured**: raw accelerometer data ׀ **Unstructured**: sound samples
	Trust	**Trustful**: ׀ **Untrustful**: Properly signed keys from a Certificate Authority are needed, "mis-annotation" by participants
	Outcome	**Complements**: publish sensing presence to social networks mobile phones
	Action	**Automation**: After associating the tag with the action, the next time the user repeats the action the user's presence state is recognized, uploaded, and shared with their social network. ׀ **Transformation**: recognizable social stereotypes or desirable behavioral patterns.
Type	Presentation	**Cyber**: ׀ **Physical**: user **Cyber-Physical**: sensor-enabled mobile phone
	Nature	**Electronic-based**: mobile phones **Software-based**: The accelerometer sensor, audio sensor, and event detector sensor **Human-based**: users **Non-Human-based**:
	Use	**Wearables**: sensor-enabled mobile phone ׀ **Surroundable**s: ׀ **Embeddables**:
	Role	**Sensor**: user, mobile phone ׀ **Actuator**:
	Engagement	**Opportunistic**: event detector sensor׀ **Participatory**: people-centric data collection
Observation	Location	**Coarse-grained**: ׀ **Fine-grained**: GPS samples
	Reach	**Full**: **Partial**: classify the location estimates of users for use by other backend classifiers
	Mobility	**Fixed**: ׀ **Mobile**: mobile phones
	Time	**Pull**: ׀ **Push**: pushing some classification to the phone and some to the backend server CenceMe publishes presence by means of either a "pull" or "push" approach.
	Mode	**Sense**: event detector sensor ׀ **Derive**: mobile phones ׀ **Manually provided**:
Capabilities	Communication	**Pragmatic communication**
	Processing	**Cloud**: ׀ **Fog/Edge**: ׀ **Mobile cloud**: x
	Storage	**Device-level**: ׀ **Network level** ׀ **Cluster level**: CenceMe portal, ClickStatus, and Facebook

Category /Dimension		Characteristic of Ubifit Garden [16]
Knowledge	Explicitness	**Tacit**: Participants manually journaled activities they performed that fitness device was not trained to infer **Explicit**: ǀ **Implicit**: real-time statistical modeling
	Structure	**Structured**: inferred data in systems **Semi-structured**: on-body sensing data **Unstructured**:
	Trust	**Trustful**: ǀ **Untrustful**: users can add to, edit, and delete inferred data in systems
	Outcome	**Complements**: assessment of noise pollution ǀ **Substitutes**:
	Action	**Automation**: infer people's activities throughout everyday life ǀ **Transformation**: awareness and sustained behavior change
Type	Presentation	**Cyber**: ǀ **Physical**: sensors include: 3-d accelerometer, barometer, humidity, visible and infrared light, temperature, microphone, and compass. **Cyber-Physical**: on-body sensing app
	Nature	**Electronic-based**: mobile phones **Software-based**: **Human-based**: user
	Use	**Wearables**: on-body sensing ǀ **Surroundable**s: ǀ **Embeddables**:
	Role	**Sensor**: on-body sensing ǀ **Actuator**:
	Engagement	**Opportunistic**: infer people's activities throughout everyday life ǀ **Participatory**:
Observation	Location	**Coarse-grained**: ǀ **Fine-grained**: fine-grain, noisy data
	Reach	**Full**: **Partial**: user context
	Mobility	**Fixed**: ǀ **Mobile**: mobile phones
	Time	**Pull**: ǀ **Push**: on-body sensing
	Mode	**Sense**: sensor data ǀ **Derive**: the activity is inferred on the MSP ǀ **Manually provided**:
Capabilities	Communication	**semantic communication**
	Processing	**Cloud**: ǀ **Fog/Edge**: interactive application and glanceable display. ǀ **Mobile cloud**:
	Storage	**Device-level**: interactive app. and glanceable display. ǀ **Network level** ǀ **Cluster level**:

Category /Dimension		Characteristic of GarbageWatch [17]
Knowledge	Explicitness	**Tacit**: citizens information about trash cans| **Explicit**: sensor garbage in cans | **Implicit**:
	Structure	**Structured**: X (garbage informations) **Semi-structured**: | **Unstructured**:
	Trust	**Trustful**: | **Untrustful**: X
	Outcome	**Complements**: X| **Substitutes**:
	Action	**Automation**: X | **Transformation**:
Type	Presentation	**Cyber**: | **Physical**: X Sensor and citizens **Cyber-Physical**: X
	Nature	**Electronic-based**: sensors in garbage cans **Human-based**: citizens
	Use	**Wearables**: mobile phones | **Surroundable**s: sensors in trash cans | **Embeddables**:
	Role	**Sensor**: X | **Actuator**:
	Engagement	**Opportunistic**: | **Participatory**: X
Observation	Location	**Coarse-grained**: | **Fine-grained**: X
	Reach	**Full**: **Partial**: X
	Mobility	**Fixed**: | **Mobile**: X
	Time	**Pull**: | **Push**: PS
	Mode	**Sense**:X | **Derive**: | **Manually provided**:
Capabilities	Communication	**semantic communication**
	Processing	**Cloud**: | **Fog/Edge**: | **Mobile cloud**: X
	Storage	**Device-level**: | **Network level** | **Cluster level**: X

Category /Dimension		Characteristic of Galaxy Zoo [18]
Knowledge	Explicitness	**Tacit**: user personal annotation ǀ **Explicit**: geo-localised measurements ǀ **Implicit**:
	Structure	**Structured**: **Semi-structured**: xǀ **Unstructured**:
	Trust	**Trustful**: ǀ **Untrustful**: x
	Outcome	**Complements**: assessment of noise pollutionǀ **Substitutes**:
	Action	**Automation**: ǀ **Transformation**: X
Type	Presentation	**Cyber**: ǀ **Physical**: X (crowd) **Cyber-Physical**:
	Nature	**Electronic-based**: mobile phones **Software-based**: **Human-based**: X (crowd) **Non-Human-based**:
	Use	**Wearables**: ǀ **Surroundable**s: ǀ **Embeddables**: X
	Role	**Sensor**: X ǀ **Actuator**:
	Engagement	**Opportunistic**: ǀ **Participatory**: people-centric data collection
Observation	Location	**Coarse-grained**: Xǀ **Fine-grained**:
	Reach	**Full**: X **Partial**:
	Mobility	**Fixed**: ǀ **Mobile**: X
	Time	**Pull**: ǀ **Push**: X
	Mode	**Sense**: ǀ **Derive**: ǀ **Manually provided**: X
Capabilities	Communication	**Conceptual communication**
	Processing	**Cloud**: ǀ **Fog/Edge**: ǀ **Mobile cloud**: X
	Storage	**Device-level**: ǀ **Network level** ǀ **Cluster level**: X

Category /Dimension		Characteristic of eBird [19]
Knowledge	Explicitness	**Tacit**: Datasources include participant observation as an eBird contributor, ǀ **Explicit**: reporting of and access to information about birds ǀ **Implicit**:
	Structure	**Structured**: X **Semi-structured**: ǀ **Unstructured**:
	Trust	**Trustful**: eBird one of the largest bio-diversity data sets in the world. ǀ **Untrustful**: participant observation
	Outcome	**Complements**: the data are used in scientificc research.ǀ **Substitutes**:
	Action	**Automation**: ǀ **Transformation**: increases the value of the data for research, promoting improved scientic outcomes.
Type	Presentation	**Cyber**: ǀ **Physical**: X **Cyber-Physical**:
	Nature	**Electronic-based**: mobile phones **Human-based**: people are keeping track of all the birds they see ǀ
	Use	**Wearables**: mobile phones ǀ **Surroundable**s: ǀ **Embeddables**:
	Role	**Sensor**: people ǀ **Actuator**:
	Engagement	**Opportunistic**: ǀ **Participatory**: people-centric data collection
Observation	Location	**Coarse-grained**: ǀ **Fine-grained**: X
	Reach	**Full**: **Partial**: X
	Mobility	**Fixed**: ǀ **Mobile**: X
	Time	**Pull**: ǀ **Push**: X
	Mode	**Sense**: ǀ **Derive**: ǀ **Manually provided**:
Capabilities	Communication	Semantic communication
	Processing	**Cloud**: ǀ **Fog/Edge**: ǀ **Mobile cloud**: main eBird web site, /
	Storage	**Device-level**: ǀ **Network level** ǀ **Cluster level**: X

Category /Dimension		Characteristic of SenSay [20]
Knowledge	Explicitness	**Tacit**: ǀ **Explicit**: sensory data / user information ǀ **Implicit**:
	Structure	**Structured**: history information **Semi-structured**: sensory data ǀ **Unstructured**:
	Trust	**Trustful**: ǀ **Untrustful**: sensory data user information
	Outcome	**Complements**: SenSay can provide remote callers with the ability to communicate the urgency of their calls, make call suggestions to users ǀ **Substitutes**:
	Action	**Automation**: ǀ **Transformation**:
Type	Presentation	**Cyber**: ǀ **Physical**: mobile phone (*sensors including accelerometers, light, and microphones*ǀ) **Cyber-Physical**: x
	Nature	**Electronic-based**: mobile phones, sensors including accelerometers, light, and microphones **Software-based**: **Human-based**: xǀ **Non-Human-based**:
	Use	**Wearables**: sensors mounted at various points on the body ǀ **Surroundable**s: ǀ **Embeddables**:
	Role	**Sensor**: x ǀ **Actuator**:
	Engagement	**Opportunistic**: ǀ **Participatory**: people-centric data collection
Observation	Location	**Coarse-grained**: ǀ **Fine-grained**: x
	Reach	**Full**: **Partial**: x
	Mobility	**Fixed**: ǀ **Mobile**: x
	Time	**Pull**: ǀ **Push**: X
	Mode	**Sense**: sensors mounted at various points on the body ǀ **Derive**: electronic calendars, address books, and task lists.ǀ **Manually provided**:
Capabilities	Communication	**Pragmatic communication**
	Processing	**Cloud**: ǀ **Fog/Edge**: SenSay Application Programming Interface (API), ǀ **Mobile cloud**:
	Storage	**Device-level**: ǀ **Network level** ǀ **Cluster level**:

Category /Dimension		Characteristic of Jog Falls [21]
Knowledge	Explicitness	**Tacit**: physician, **Explicit**: health data ǀ **Implicit**: analysis of health data, physicians designed the system
	Structure	**Structured**: health data **Semi-structured**: sensor data ǀ **Unstructured**:
	Trust	**Trustful**: X ǀ **Untrustful**:
	Outcome	**Complements**: enabling physicians to be better coaches ǀ **Substitutes**:
	Action	**Automation**: activity and energy expenditure monitoring, diet-logging, ǀ **Transformation**: analysis of health data for patients and physicians empower patients to manage their life
Type	Presentation	**Cyber**: ǀ **Physical**: ǀ physician / **Cyber-Physical**: sensor devices /
	Nature	**Electronic-based**: / sensor devices /mobile phones **Software-based**: **Human-based**: physician, **Non-Human-based**:
	Use	**Wearables**: body wearable sensors ǀ **Surroundable**s: sensor devices ǀ **Embeddables**:
	Role	**Sensor**: X ǀ **Actuator**: physician
	Engagement	**Opportunistic**: people-centric data collection ǀ **Participatory**:
Observation	Location	**Coarse-grained**: ǀ **Fine-grained**: FG
	Reach	**Full**: **Partial**: P
	Mobility	**Fixed**: x ǀ **Mobile**: x
	Time	**Pull**: ǀ **Push**: x
	Mode	**Sense**: x ǀ **Derive**: fusion of heart rate and accelerometer data ǀ **Manually provided**:
Capabilities	Communication	**Pragmatic communication**
	Processing	**Cloud**: backend server ǀ **Fog/Edge**: mobile phones ǀ
	Storage	**Device-level**: backend server ǀ **Network level** ǀ **Cluster level**: backend server that is responsible for aggregating and storing the data

Category /Dimension		Characteristic of MobAsthma [22]
Knowledge	Explicitness	**Tacit**: asthma specialists and allergists **Explicit**: measurements from medical devices, pollution data ǀ **Implicit**: application analyzes, in real time,
	Structure	**Structured**: X **Semi-structured**: Xǀ **Unstructured**:
	Trust	**Trustful**: Xǀ **Untrustful**:
	Outcome	**Complements**: lets asthma specialists and allergists investigate the relationships between personal exposure to air pollution ǀ **Substitutes**:
	Action	**Automation**: ǀ **Transformation**: MobAsthma, a mobile asthma and pollution monitor.
Type	Presentation	**Cyber**: mobile phone **Physical**: asthma specialists and allergists **Cyber-Physical**: pollution sensors
	Nature	**Electronic-based**: mobile phones **Software-based**: **Human-based**: user **Non-Human-based**:
	Use	**Wearables**: xǀ **Surroundable**s: pollution sensor ǀ **Embeddables**:
	Role	**Sensor**: x ǀ **Actuator**:
	Engagement	**Opportunistic**: ǀ **Participatory**: people-centric data collection
Observation	Location	**Coarse-grained**: ǀ **Fine-grained**: x
	Reach	**Full**: **Partial**: X
	Mobility	**Fixed**: x pollution sensor ǀ **Mobile**: x
	Time	**Pull**: ǀ **Push**: x
	Mode	**Sense**: X ǀ **Derive**: Each data entry is combined with the last valid GPS location plus additional information ǀ **Manually provided**:
Capabilities	Communication	**Pragmatic communication**
	Processing	**Cloud**: database server ǀ **Fog/Edge**: ǀ **Mobile cloud**:
	Storage	**Device-level**: ǀ **Network level** ǀ **Cluster level**: database server

Category /Dimension		Characteristic of Transafe [23]
Knowledge	Explicitness	**Tacit**: ǀ collective intelligence about places **Explicit**: social media, user place-marking, timestamps ǀ **Implicit**: analyze public sentiments
	Structure	**Structured**: user place-marking, timestamps **Semi-structured**: social media ǀ **Unstructured**:
	Trust	**Trustful**: Stakeholder ǀ **Untrustful**: users
	Outcome	**Complements**: the visualization of this crowdsourced safety perception information will increase the commuter's awareness ǀ **Substitutes**:
	Action	**Automation**: ǀ **Transformation**: great potential to discover patterns of public sentiments about places in the City of Melbourne
Type	Presentation	**Cyber**: ǀ **Physical**: ǀusers **Cyber-Physical**: Mobile phone sensors
	Nature	**Electronic-based**: mobile phones **Software-based**: ǀ **Human-based**: ǀ users **Non-Human-based**:
	Use	**Wearables**: x ǀ **Surroundable**s: ǀ **Embeddables**:
	Role	**Sensor**: x ǀ **Actuator**:
	Engagement	**Opportunistic**: ǀ **Participatory**: people-centric data collection
Observation	Location	**Coarse-grained**: ǀ **Fine-grained**: FG
	Reach	**Full**: **Partial**: X
	Mobility	**Fixed**: ǀ **Mobile**: x
	Time	**Pull**: ǀ **Push**: X
	Mode	**Sense**:X ǀ **Derive**: ǀ **Manually provided**:
Capabilities	Communication	**pragmatic communication**
	Processing	**Cloud**: Transafe database ǀ **Fog/Edge**: ǀ
	Storage	**Device-level**: ǀ **Network level** ǀ **Cluster level**: Transafe database

Category /Dimension		Characteristic of Neo-natal Care & AAL [24]
Knowledge	Explicitness	**Tacit**: physician **Explicit**: collected data (e.g. blood pressure, body weight, heart rate ǀ **Implicit**: rule-based algorithm analyses the collected data and recognizes exceeding of certain thresholds
	Structure	**Structured**: collected data (e.g. blood pressure, body weight, heart rate **Semi-structured**: ǀ **Unstructured**:
	Trust	**Trustful**: collected data ǀ **Untrustful**:
	Outcome	**Complements**: support elderly people in their daily routine to allow an independent and safe lifestyle ǀ **Substitutes**:
	Action	**Automation**: ǀ **Transformation**: support elderly people and people with special needs in their daily routine.
Type	Presentation	**Cyber**: rule-based algorithm **Physical**: ǀ physician, user **Cyber-Physical**: smart objects
	Nature	**Electronic-based**: mobile phones, RFID in combination with Near Field Communication (NFC) and mobile phones. **Software-based**: smart objects **Human-based**: physician ǀ
	Use	**Wearables**: smart objects ǀ **Surroundable**s: smart objects ǀ **Embeddables**:
	Role	**Sensor**: smart objects ǀ **Actuator**: The physician "on the other side of the loop" is obliged to check the event, to give, telemedical advice (feedback/reminder) or react, user sends data
	Engagement	**Opportunistic**: collected data **Participatory**: people-centric data collection
Observation	Location	**Coarse-grained**: ǀ **Fine-grained**: FG
	Reach	**Full**: **Partial**: P
	Mobility	**Fixed**: ǀ **Mobile**: X
	Time	**Pull**: Xǀ **Push**: X
	Mode	**Sense**: X ǀ **Derive**: xǀ **Manually provided**: X
Capabilities	Communication	**Pragmatic communication**
	Processing	**Cloud**: server sideǀ **Fog/Edge**: Java software application installed on the mobile phone. ǀ **Mobile cloud**:
	Storage	**Device-level**: ǀ **Network level** ǀ **Cluster level**: server side

Category /Dimension		Characteristic of AAL & Navigation [25]
Knowledge	Explicitness	**Tacit**: ǀ **Explicit**: ǀ **Implicit**: Intelligent video systems (IVS) and analytics (IVA)
	Structure	**Structured**: **Semi-structured**: ǀ **Unstructured**: video data
	Trust	**Trustful**: xǀ **Untrustful**:
	Outcome	**Complements**: video data to aid the elderly and visually handicapped ǀ **Substitutes**: blind can understand the environment around him through the set of stereo earphone
	Action	**Automation**: ǀ **Transformation**: transform video surveillance into a real-time, proactive, event-driven process.
Type	Presentation	**Cyber**: ǀ **Physical**: ǀ security team/ blind user **Cyber-Physical**: high-performance embedded cameras combine video sensing
	Nature	**Electronic-based**: high-performance embedded cameras combine video sensing **Software-based**: ǀ **Human-based**: ǀ security team **Non-Human-based**:
	Use	**Wearables**: headgear with a digital video camera and a set of stereo earphones interconnected. ǀ **Surroundable**s: ǀ **Embeddables**:
	Role	**Sensor**: X ǀ **Actuator**: security team
	Engagement	**Opportunistic**: ǀ **Participatory**: people-centric data collection
Observation	Location	**Coarse-grained**: ǀ **Fine-grained**: X
	Reach	**Full**: **Partial**: X
	Mobility	**Fixed**: X ǀ **Mobile**: X
	Time	**Pull**: ǀ **Push**: X
	Mode	**Sense**: Xǀ **Derive**: Xǀ **Manually provided**:
Capabilities	Communication	**Pragmatic communication**
	Processing	**Cloud**: server side ǀ **Fog/Edge**: low-level image processing at the level of sensor acquisition. ǀ **Mobile cloud**:
	Storage	**Device-level**: ǀ **Network level** ǀ **Cluster level**: X

Category /Dimension		Characteristic of Smart Clothing Monitoring [26]
Knowledge	Explicitness	**Tacit**: ǀ **Explicit**: physiological signals or psychological data ǀ **Implicit**: healthcare big data analysis
	Structure	**Structured**: **Semi-structured**: physiological signals or psychological data ǀ **Unstructured**:
	Trust	**Trustful**: xǀ **Untrustful**:
	Outcome	**Complements**: healthcare big data by sustainable health monitoring ǀ **Substitutes**:
	Action	**Automation**: ǀ **Transformation**: achieve personalized healthcare value-added services on the basis of physiological information.
Type	Presentation	**Cyber**: ǀ **Physical**: ǀ five physiological sensors into smart clothing. **Cyber-Physical**:
	Nature	**Electronic-based**: five physiological sensors into smart clothing. smartphone ortablet **Software-based**: **Human-based**:user
	Use	**Wearables**: five physiological sensors into smart clothing ǀ **Surroundable**s: ǀ **Embeddables**:
	Role	**Sensor**: smart clothing integrates a variety of biosensors ǀ **Actuator**:
	Engagement	**Opportunistic**: ǀ **Participatory**: people-centric data collection
Observation	Location	**Coarse-grained**: x ǀ **Fine-grained**:
	Reach	**Full**: **Partial**: P
	Mobility	**Fixed**: ǀ **Mobile**: X
	Time	**Pull**: ǀ **Push**: X
	Mode	**Sense**: Xǀ **Derive**: ǀ **Manually provided**:
Capabilities	Communication	**Pragmatic communication BAN**
	Processing	**Cloud**: health cloud platform ǀ **Fog/Edge**: the patient intelligent mobile terminal application software, the doctor intelligent mobile terminal ǀ **Mobile cloud**:
	Storage	**Device-level**: ǀ **Network level** ǀ **Cluster level**: health cloud platform

Category /Dimension		Characteristic of ECG Health Monitoring [27]
Knowledge	Explicitness	**Tacit**: ǀ healthcare professional **Explicit**: ECG data ǀ **Implicit**:
	Structure	**Structured**:X **Semi-structured**: ǀ **Unstructured**:
	Trust	**Trustful**: Embedding watermark in the ECG signal will ensure the authenticity ǀ **Untrustful**:
	Outcome	**Complements**: potentially revolutionize the healthcare industry in terms of improving access to patient information, ǀ **Substitutes**:
	Action	**Automation**: healthcare professionals may be able to access patient information, store it, and analyze it in a real-time manner to monitor and track the patient. ǀ **Transformation**:
Type	Presentation	**Cyber**: ǀ mobile phones **Physical**: ǀ healthcare professional **Cyber-Physical**:
	Nature	**Electronic-based**: mobile phones **Software-based**: ǀ **Human-based**: ǀ **Non-Human-based**:
	Use	**Wearables**: X ǀ **Surroundable**s: ǀ **Embeddables**:
	Role	**Sensor**: X ǀ **Actuator**:
	Engagement	**Opportunistic**: people-centric data collection ǀ **Participatory**:
Observation	Location	**Coarse-grained**: ǀ **Fine-grained**: X
	Reach	**Full**: **Partial**: X
	Mobility	**Fixed**: ǀ **Mobile**: X
	Time	**Pull**: Xǀ **Push**:
	Mode	**Sense**:X ǀ **Derive**: ǀ **Manually provided**:
Capabilities	Communication	**Pragmatic communication**
	Processing	**Cloud**: based on the cloud ǀ **Fog/Edge**: ǀ
	Storage	**Device-level**: ǀ **Network level** ǀ **Cluster level**: based on the cloud

Category /Dimension		Characteristic of Prognosis [28]
Knowledge	Explicitness	**Tacit**: ǀ healthcare professionals **Explicit**: domain knowledge and medical research ǀ **Implicit**: Analytics prognosis
	Structure	**Structured**: Health indicators **Semi-structured**: ǀ **Unstructured**:
	Trust	**Trustful**: data streams of IoT health data ǀ **Untrustful**:
	Outcome	**Complements**: descriptive analytics visualisations of activities ǀ **Substitutes**: Analytics can also be applied in the form of prognosis
	Action	**Automation**: ǀ **Transformation**: predicting the future medical condition of a patient
Type	Presentation	**Cyber**: ǀ **Physical**: ǀ healthcare professionals **Cyber-Physical**: data streams of IoT health data
	Nature	**Electronic-based**: mobile phones **Software-based**: ǀ **Human-based**: healthcare professionals **Non-Human-based**:
	Use	**Wearables**: X ǀ **Surroundable**s: ǀ **Embeddables**:
	Role	**Sensor**: X ǀ **Actuator**:
	Engagement	**Opportunistic**: ǀ **Participatory**: people-centric data collection
Observation	Location	**Coarse-grained**: ǀ **Fine-grained**: X
	Reach	**Full**: **Partial**: X
	Mobility	**Fixed**: ǀ **Mobile**: X
	Time	**Pull**: Xǀ **Push**:
	Mode	**Sense**: X ǀ **Derive**: X ǀ **Manually provided**:
Capabilities	Communication	**Pragmatic communication**
	Processing	**Cloud**:X ǀ **Fog/Edge**: ǀ **Mobile**
	Storage	**Device-level**: ǀ **Network level** ǀ **Cluster level**: X

Category /Dimension		Characteristic of Wellness Recommendations [29]
Knowledge	Explicitness	**Tacit**: ǀ medical experts **Explicit**: Knowledge Bases of KCL. ǀ **Implicit**:
	Structure	**Structured**: Health indicators **Semi-structured**: ǀ **Unstructured**:
	Trust	**Trustful**: data streams of IoT health data ǀ **Untrustful**:
	Outcome	**Complements**: personalized healthcare and wellness support ǀ **Substitutes**:
	Action	**Automation**: ǀ **Transformation**: Behavior change and healthy lifestyle promotion
Type	Presentation	**Cyber**: ǀ **Physical**: ǀ smartphone, smartwatch,user **Cyber-Physical**:
	Nature	**Electronic-based**: smartphone, inertial sensors of the smartwatch **Software-based**: ǀ **Human-based**: user **Non-Human-based**:
	Use	**Wearables**: X ǀ **Surroundable**s: ǀ **Embeddables**:
	Role	**Sensor**: X ǀ **Actuator**:
	Engagement	**Opportunistic**: ǀ **Participatory**: people-centric data collection
Observation	Location	**Coarse-grained**: ǀ **Fine-grained**: X
	Reach	**Full**: **Partial**: X
	Mobility	**Fixed**: ǀ **Mobile**: X
	Time	**Pull**: Xǀ **Push**:
	Mode	**Sense**: application continuously captures the user's body motion ǀ **Derive**: X ǀ **Manually provided**:
Capabilities	Communication	**Pragmatic communication**
	Processing	**Cloud**: public clouds ǀ **Fog/Edge**: ǀ **Mobile**
	Storage	**Device-level**: ǀ **Network level** ǀ **Cluster level**: public clouds

Category /Dimension		Characteristic of Traffic Control [30]
Knowledge	Explicitness	**Tacit**: ǀ **Explicit**: real-time data received from a traffic detector system. ǀ **Implicit**: the INdividual Detection Evaluation (INDE) and COmbined Detection Evaluation (CODE) algorithms
	Structure	**Structured**: real-time data received from a traffic detector system **Semi-structured**: traffic measurements ǀ **Unstructured**:
	Trust	**Trustful**: x ǀ **Untrustful**:
	Outcome	**Complements**: Timely detection of accidents, vehicle breakdowns, and events that obstruct the normal flow of traffic ǀ **Substitutes**:
	Action	**Automation**: incident detection algorithms on expressways ǀ **Transformation**:
Type	Presentation	**Cyber**: ǀ **Physical**: ǀ video-based detector system **Cyber-Physical**:
	Nature	**Electronic-based**: video-based detector system **Software-based**: **Human-based**: **Non-Human-based**:
	Use	**Wearables**: ǀ **Surroundable**s: x ǀ **Embeddables**:
	Role	**Sensor**: X ǀ **Actuator**:
	Engagement	**Opportunistic**: x ǀ **Participatory**:
Observation	Location	**Coarse-grained**: x ǀ **Fine-grained**:
	Reach	**Full**: **Partial**: X
	Mobility	**Fixed**: ǀ **Mobile**: X
	Time	**Pull**: X ǀ **Push**:
	Mode	**Sense**: application continuously captures the user's body motion ǀ **Derive**: X ǀ **Manually provided**:
Capabilities	Communication	**Semantic communication**
	Processing	**Cloud**: x ǀ **Fog/Edge**: ǀ **Mobile**
	Storage	**Device-level**: ǀ **Network level** ǀ **Cluster level**: x

Category /Dimension		Characteristic of Pedestrian & Car Detection [31]
Knowledge	Explicitness	**Tacit**: ǀ **Explicit**: information from past detections ǀ **Implicit**: analytics to compute characteristics of pedestrian and traffic flow
	Structure	**Structured**: information from past detections **Semi-structured** and **Unstructured**: real-time data pertaining to pedestrian- and vehicular-driven traffic (e.g., foot, bicycle, pets, cars) and environmental conditions
	Trust	**Trustful**: X ǀ **Untrustful**:
	Outcome	**Complements**: efficient pedestrian and vehicle detection ǀ **Substitutes**:
	Action	**Automation**: ǀ **Transformation**: guide traffic navigation and to enhance public safety.
Type	Presentation	**Cyber**: ǀ **Physical**: ǀ **Cyber-Physical**: sensor nodes will collect and perform analytics in-situ
	Nature	**Electronic-based**: sensor nodes will collect and perform analytics in-situ **Software-based**: **Human-based**: **Non-Human-based**:
	Use	**Wearables**: ǀ **Surroundable**s: sensor nodes ǀ **Embeddables**: X
	Role	**Sensor**: X ǀ **Actuator**:
	Engagement	**Opportunistic**: sensor nodes will collect and perform analytics in-situ ǀ **Participatory**:
Observation	Location	**Coarse-grained**: Xǀ **Fine-grained**:
	Reach	**Full**: **Partial**: X
	Mobility	**Fixed**: ǀ **Mobile**: X
	Time	**Pull**: ǀ **Push**: X
	Mode	**Sense**: sensor nodes will collect and perform analytics in-situ ǀ **Derive**: X ǀ **Manually provided**:
Capabilities	Communication	**Semantic communication**
	Processing	**Cloud**: server hosted at Georgia Tech ǀ **Fog/Edge**: "analytics on the edge"
	Storage	**Device-level**: "analytics on the edge" ǀ **Network level** ǀ **Cluster level**: server hosted at Georgia Tech

Category /Dimension		Characteristic of Travel Routing [33]
Knowledge	Explicitness	**Tacit**: ǀ **Explicit**: ǀ **Implicit**: X
	Structure	**Structured**: historical data **Semi-structured** and **Unstructured**: streamed online data and a rich dependency structure
	Trust	**Trustful**: x ǀ **Untrustful**:
	Outcome	**Complements**: ǀ **Substitutes**: estimates traffic flow in areas with low sensor coverage
	Action	**Automation**: estimating future traffic situations for route calculation. ǀ **Transformation**: individual trip planning that incorporates future traffic hazards in routing.
Type	Presentation	**Cyber**: ǀ **Physical**: ǀ **Cyber-Physical**: SCATS sensors
	Nature	**Electronic-based**: SCATS sensors **Software-based**: **Human-based**: **Non-Human-based**:
	Use	**Wearables**: ǀ **Surroundable**s: SCATS sensors ǀ **Embeddables**:
	Role	**Sensor**: X ǀ **Actuator**:
	Engagement	**Opportunistic**: xǀ **Participatory**:
Observation	Location	**Coarse-grained**: Xǀ **Fine-grained**:
	Reach	**Full**: **Partial**: X
	Mobility	**Fixed**: ǀ **Mobile**: X
	Time	**Pull**: ǀ **Push**: X
	Mode	**Sense**: sensor nodes will collect and perform analytics in-situ ǀ **Derive**: X ǀ **Manually provided**:
Capabilities	Communication	**3**
	Processing	**Cloud**: [2]Dublin SCATS data: http://www.dublinked.ie [3]OpenStreetMap: http://www.openstreetmap.org ǀ **Fog/Edge**:
	Storage	**Device-level**: ǀ **Network level** ǀ **Cluster level**: Dublin SCATS data: http://www.dublinked.ie and OpenStreetMap: http://www.openstreetmap.org

Category /Dimension		Characteristic of Smart Parking [34]
Knowledge	Explicitness	**Tacit**: ׀ **Explicit**: ׀ **Implicit**: X
	Structure	**Structured**: historical vehicular data **- Semi-structured** and **Unstructured**:
	Trust	**Trustful**: x ׀ **Untrustful**:
	Outcome	**Complements**: smart parking service that combines geographic location information, parking availability, traffic, and reservation information ׀ **Substitutes**:
	Action	**Automation**: ׀ **Transformation**: allows prediction and optimisation of parking availability.
Type	Presentation	**Cyber**: ׀
	Nature	**Physical**: ׀ **Cyber-Physical**: sensors, actuators, controllers, GPS devices, mobile phones, and other Internet access equipments, **Electronic-based**: sensors, actuators, controllers, GPS devices, mobile phones, and other Internet access equipments, **Software-based**: **Human-based**: **Non-Human-based**:
	Use	**Wearables**: mobile phones ׀ **Surroundable**s: cameras and street lights ׀ **Embeddables**: GPS devices , controllers
	Role	**Sensor**: X ׀ **Actuator**: X
	Engagement	**Opportunistic**: x׀ **Participatory**:
Observation	Location	**Coarse-grained**: X׀ **Fine-grained**:
	Reach	**Full**: **Partial**: X
	Mobility	**Fixed**: ׀ **Mobile**: X
	Time	**Pull**: ׀ **Push**: X
	Mode	**Sense**: sensor nodes will collect and perform analytics in-situ ׀ **Derive**: X ׀ **Manually provided**:
Capabilities	Communication	**Semantic communic. /** VANETs were primarily designed to support the communication between different vehicles (V2 V)and the communication between vehicles and the roadside infrastructures (V2I)
	Processing	**Cloud**: cloud-based urban traffic control system ׀ **Fog/Edge**:
	Storage	**Device-level**: ׀ **Network level** ׀ **Cluster level**: cloud-based urban traffic control system

Category /Dimension		Characteristic of Parking Anomaly Detection [35]
Knowledge	Explicitness	**Tacit**: ׀ **Explicit**: ׀ **Implicit**: simulation models for parking traces
	Structure	**Structured**: statistics of real parking data **- Semi-structured** Real data, from a commercial deployment **Unstructured**:
	Trust	**Trustful**: x ׀ **Untrustful**:
	Outcome	**Complements**: unsupervised form of self-organising maps (SOM) clustering to the classification of parking spaces according to spatio-temporal patterns. ׀ **Substitutes**:
	Action	**Automation**: X׀ **Transformation**:
Type	Presentation	**Cyber**: ׀
	Nature	**Physical**: 370 wireless sensors ׀ **Cyber-Physical**: **Electronic-based**: field sensor devices, **Software-based**: **Human-based**: **Non-Human-based**:
	Use	**Wearables**: ׀ **Surroundable**s: field sensor devices,׀ **Embeddables**: s
	Role	**Sensor**: X ׀ **Actuator**: X
	Engagement	**Opportunistic**: x׀ **Participatory**:
Observation	Location	**Coarse-grained**: X׀ **Fine-grained**:
	Reach	**Full**: **Partial**: X
	Mobility	**Fixed**: x׀ **Mobile**:
	Time	**Pull**: ׀ **Push**: X
	Mode	**Sense**: x ׀ **Derive**: X ׀ **Manually provided**:
Capabilities	Communication	**Semantic communication**
	Processing	**Cloud: backend servers ׀ Fog/Edge:**
	Storage	**Device-level**: ׀ **Network level ׀ Cluster level**: backend servers

Category /Dimension		Characteristic of Cultural Behaviour [36]
Knowledge	Explicitness	**Tacit**: x | **Explicit**: | **Implicit**: analyse cultural behaviour using visualisations within an associative model
	Structure	**Structured**, **Semi-structured** , **Unstructured**: Geo-Spatial and Social Network data, Multimedia (MM), multiple domain vocabularies, classifiers and ontologies.
	Trust	**Trustful**: x | **Untrustful**:
	Outcome	**Complements**: classify movement in museums from sensors with semantic enrichment from knowledge bases of cultural exhibits and social media of cultural tourism | **Substitutes**:
	Action	**Automation**: | **Transformation**: analyse cultural behaviour using visualisations within an associative model
Type	Presentation	**Cyber**: | **Physical**: mobile device , user | **Cyber-Physical**:
	Nature	**Electronic-based**: mobile device **Software-based**: **Human-based**: ysers **Non-Human-based**:
	Use	**Wearables**: mobile device | **Surroundable**s: field sensor devices,| **Embeddables**: s
	Role	**Sensor**: X | **Actuator**:
	Engagement	**Opportunistic**: x| **Participatory**:
Observation	Location	**Coarse-grained**: X| **Fine-grained**:
	Reach	**Full**: X **Partial**:
	Mobility	**Fixed**: | **Mobile**: X
	Time	**Pull**: | **Push**: X
	Mode	**Sense**: x | **Derive**: X | **Manually provided**:
Capabilities	Communication	**Semantic communication**
	Processing	**Cloud: backend servers | Fog/Edge:**
	Storage	**Device-level**: | **Network level** | **Cluster level**: backend servers

Category /Dimension		Characteristic of Police Situational Awareness [37]
Knowledge	Explicitness	**Tacit**: Officers ǀ **Explicit**: ǀ **Implicit**: Visualisation that taps the human cognitive ability to recognise patterns
	Structure	**Structured**, **Semi-structured** , **Unstructured**: Geo-Spatial and Social Network data, Multimedia (MM), multiple domain vocabularies, classifiers and ontologies.
	Trust	**Trustful**: x ǀ **Untrustful**:
	Outcome	**Complements**: Officers are equipped with mobile devices that tap into crime data and spatio-temporal sensor data to show interactive alerts of hotspots, risk profiles, and on demand chemical plume models ǀ **Substitutes**:
	Action	**Automation**: ǀ **Transformation**: helping law enforcement officers increase their situational awareness
Type	Presentation	**Cyber**: ǀ **Physical**: mobile device , Officers ǀ **Cyber-Physical**:
	Nature	**Electronic-based**: mobile device **Software-based**: **Human-based**: Officers **Non-Human-based**:
	Use	**Wearables**: mobile device ǀ **Surroundable**s: ǀ **Embeddables**: s
	Role	**Sensor**: X ǀ **Actuator**:
	Engagement	**Opportunistic**: xǀ **Participatory**: X
Observation	Location	**Coarse-grained**: Xǀ **Fine-grained**:
	Reach	**Full**: X **Partial**:
	Mobility	**Fixed**: ǀ **Mobile**: X
	Time	**Pull**: ǀ **Push**: X
	Mode	**Sense**: x ǀ **Derive**: X ǀ **Manually provided**:
Capabilities	Communication	**Semantic communication**
	Processing	**Cloud**: database server ǀ **Fog/Edge**:
	Storage	**Device-level**: ǀ **Network level** ǀ **Cluster level**: database server

Category /Dimension		Characteristic of Public Safety Monitoring [38]
Knowledge	Explicitness	**Tacit**: Officers ǀ **Explicit**: ǀ **Implicit**: video analytics in detecting movement, intruders or targets
	Structure	**Structured**, **Semi-structured** X, **Unstructured**: X
	Trust	**Trustful**: x ǀ **Untrustful**:
	Outcome	**Complements**: Cǀ **Substitutes**:
	Action	**Automation**: smart video analytics systems can proactively monitor, automatically recognise and bring to notice situations, ǀ **Transformation**:
Type	Presentation	**Cyber**: ǀ **Physical**: mobile device , Officers ǀ **Cyber-Physical**: Video surveillance systems
	Nature	**Electronic-based**: cameras **Software-based**: **Human-based**: Officers **Non-Human-based**:
	Use	**Wearables**: mobile device ǀ **Surroundable**s: cameras ǀ **Embeddables**: s
	Role	**Sensor**: X ǀ **Actuator**: x
	Engagement	**Opportunistic**: xǀ **Participatory**: X
Observation	Location	**Coarse-grained**: Xǀ **Fine-grained**:
	Reach	**Full**: X **Partial**:
	Mobility	**Fixed**: ǀ **Mobile**: X
	Time	**Pull**: ǀ **Push**: X
	Mode	**Sense**: x ǀ **Derive**: X ǀ **Manually provided**:
Capabilities	Communication	**Semantic communication**
	Processing	**Cloud**: database server ǀ **Fog/Edge**:
	Storage	**Device-level**: ǀ **Network level** ǀ **Cluster level**: database server

Category /Dimension		Characteristic of Smart Building Heating [42]
Knowledge	Explicitness	**Tacit**: users | **Explicit**: | **Implicit**: derive diagnosis rules and behaviour of a specific building, making it sensitive to new anomalies
	Structure	**Structured**, **Semi-structured** , **Unstructured**: x
	Trust	**Trustful**: x | **Untrustful**:
	Outcome	**Complements**: | **Substitutes**: analytics can be applied to energy monitoring used in heat- ing for smart buildings
	Action	**Automation**: , | **Transformation**: diagnose anomalies in the building temperature, for example, break downs of the cooling system, high occupancy of rooms, or open windows caus- ing air exchange with the external surroundings.
Type	Presentation	**Cyber**: | **Physical**: mobile device , | **Cyber-Physical**: temperature sensors and a heating system
	Nature	**Electronic-based**: 271 sensors **Software-based**: **Human-based**: **Non-Human-based**:
	Use	**Wearables**: mobile device | **Surroundable**s: temperature sensors | **Embeddables**: s
	Role	**Sensor**: X | **Actuator**: x
	Engagement	**Opportunistic**: x| **Participatory**: X
Observation	Location	**Coarse-grained**: X| **Fine-grained**:
	Reach	**Full**: X **Partial**:
	Mobility	**Fixed**: | **Mobile**: X
	Time	**Pull**: | **Push**: X
	Mode	**Sense**: x | **Derive**: X | **Manually provided**: x
Capabilities	Communication	**Semantic communication**
	Processing	**Cloud**: server | **Fog/Edge**:
	Storage	**Device-level**: | **Network level** | **Cluster level**: server

Category /Dimension		Characteristic of Memory Augmentation [43]
Knowledge	Explicitness	**Tacit**: users | **Explicit**: | **Implicit**: insights from mining the digital traces left by IoT data from cameras, wearables, mobile phones, and smart appliances.
	Structure	**Structured**, **Semi-structured** , **Unstructured**: x
	Trust	**Trustful**: x | **Untrustful**:
	Outcome	**Complements**: | **Substitutes**: life-logging systems to augment human memory with recorded data, real-world search for objects and interactions with people and a system
	Action	**Automation**: | **Transformation**: improve urban mobility systems by studying large-scale human mobility patterns
Type	Presentation	**Cyber**: | **Physical**: mobile device ,| **Cyber-Physical**: Video surveillance systems
	Nature	**Electronic-based**: surveillance cameras **Software-based**: **Human-based**: Officers **Non-Human-based**:
	Use	**Wearables**: mobile device | **Surroundable**s: surveillance cameras | **Embeddables**: s
	Role	**Sensor**: X | **Actuator**: x
	Engagement	**Opportunistic**: x| **Participatory**: X
Observation	Location	**Coarse-grained**: X| **Fine-grained**:
	Reach	**Full**: X **Partial**:
	Mobility	**Fixed**: | **Mobile**: X
	Time	**Pull**: | **Push**: X
	Mode	**Sense**: x | **Derive**: X | **Manually provided**:
Capabilities	Communication	**Semantic communication**
	Processing	**Cloud**: X | **Fog/Edge**:
	Storage	**Device-level**: | **Network level** | **Cluster level**: x

Category /Dimension		Characteristic of Wearable Lifestyle Monitor [41]
Knowledge	Explicitness	**Tacit**: users ǀ **Explicit**: ǀ **Implicit**: detecting anomalies and also for classifying high-dimensional data
	Structure	**Structured**, **Semi-structured** , **Unstructured**: accelerometer data from a wearable personal digital
	Trust	**Trustful**: x ǀ **Untrustful**:
	Outcome	**Complements**: discovering patterns to classify activity from sensor data ǀ **Substitutes**:
	Action	**Automation**: ǀ **Transformation**: analytical tools that form a basis for smart and intelligent devices and, in this example, for activity tracking and monitoring
Type	Presentation	**Cyber**: ǀ **Physical**: mobile device , wearable or implantable devices ǀ **Cyber-Physical**:
	Nature	**Electronic-based**: wearable or implantable devices **Software-based**: **Human-based**: **Non-Human-based**:
	Use	**Wearables**: wearable or implantable devices ǀ **Surroundable**s: ǀ **Embeddables**: s
	Role	**Sensor**: X ǀ **Actuator**: x
	Engagement	**Opportunistic**: xǀ **Participatory**:
Observation	Location	**Coarse-grained**: ǀ **Fine-grained**: X
	Reach	**Full**: **Partial**: X
	Mobility	**Fixed**: ǀ **Mobile**: X
	Time	**Pull**: ǀ **Push**: X
	Mode	**Sense**: x ǀ **Derive**: X ǀ **Manually provided**:
Capabilities	Communication	**Semantic communication -** a network of sensors and bio detectors that are connected via bluetooth to a radio device or a cell phone that transmits data to a central server on a real time basis
	Processing	**Cloud**: X ǀ **Fog/Edge**:
	Storage	**Device-level**: ǀ **Network level** ǀ **Cluster level**: X

Category /Dimension		Characteristic of Disaster Detection & Warning[45]
Knowledge	Explicitness	**Tacit**: ǀ **Explicit**: ǀ **Implicit**: disaster-detection system that works on heterogenous streams of sensor data.
	Structure	**Structured**, **Semi-structured** , **Unstructured mobile network utilization data, social media streams (twitter), data on bus and train networks, integrate expert feedback (crowdsourcing)**
	Trust	**Trustful**: x ǀ **Untrustful**: X
	Outcome	**Complements**: Intelligent Sensor Agents (ISAs) that produce anomalies, low-level events with location and time information, ǀ **Substitutes**:
	Action	**Automation**: ǀ **Transformation**: various data sources enable early response and offer situative insights when integrated in an on-line incident recognition system.
Type	Presentation	**Cyber**: ǀ **Physical**: mobile device, **bus and train sensors** ǀ **Cyber-Physical**:
	Nature	**Electronic-based**: mobile device **Software-based**: **Human-based**: experts **Non-Human-based**:
	Use	**Wearables**: mobile devices ǀ **Surroundable**s: ǀ **Embeddables**: **bus and train sensors**
	Role	**Sensor**: X ǀ **Actuator**: x
	Engagement	**Opportunistic**: xǀ **Participatory**: x (crowdsourcing)
Observation	Location	**Coarse-grained**: ǀ **Fine-grained**: X
	Reach	**Full**: **Partial**: X
	Mobility	**Fixed**: ǀ **Mobile**: X
	Time	**Pull**: ǀ **Push**: X
	Mode	**Sense**: x ǀ **Derive**: Round Table (RT) components that fuse heterogenous sources together by mapping them to a common incident ontology ǀ **Manually provided**:
Capabilities	Communication	Pragmatic Communications
	Processing	**Cloud**: x ǀ **Fog/Edge**:
	Storage	**Device-level**: ǀ **Network level** ǀ **Cluster level**: x

Category /Dimension		Characteristic of Urban Disaster Storytelling [43]
Knowledge	Explicitness	**Tacit**: ǀ **Explicit**: ǀ **Implicit**: mining multi-modal information, monitor real time urban emergency events.
	Structure	**Structured, Semi-structured , Unstructured:** utilise social media events from multi-modal microblog posts (videos, images and text)
	Trust	**Trustful**: x ǀ **Untrustful**: X
	Outcome	**Complements**: to mine semantic, spatiotemporal, and visual information producing a story.ǀ Substitutes:
	Action	**Automation**: ǀ **Transformation**: increase the situational awareness of emergency response teams.
Type	Presentation	**Cyber**: ǀ **Physical**: mobile device ǀ **Cyber-Physical**:
	Nature	**Electronic-based**: mobile device **Software-based**: **Human-based**: experts **Non-Human-based**:
	Use	**Wearables**: mobile devices ǀ **Surroundable**s: ǀ **Embeddables**:
	Role	**Sensor**: X ǀ **Actuator**: x
	Engagement	**Opportunistic**: xǀ **Participatory**:
Observation	Location	**Coarse-grained**: ǀ **Fine-grained**: X
	Reach	**Full**: **Partial**: X
	Mobility	**Fixed**: ǀ **Mobile**: X
	Time	**Pull**: ǀ **Push**: X
	Mode	**Sense**: x ǀ **Derive**: X **Manually provided**:
Capabilities	Communication	Pragmatic Communication
	Processing	**Cloud**: x ǀ **Fog/Edge**:
	Storage	**Device-level**: ǀ **Network level** ǀ **Cluster level**: x

Category /Dimension		Characteristic of Wind Forecasting [41]
Knowledge	Explicitness	**Tacit**: ǀ **Explicit**: ǀ **Implicit**: Artificial Neural Network is used on this data and historical data to perform the forecasting.
	Structure	**Structured, Semi-structured , Unstructured:** Data is collected from wind-speed sensors in wind turbines
	Trust	**Trustful**: x ǀ **Untrustful**:
	Outcome	**Complements**: ǀ Substitutes: Artificial Neural Network is used on this data and historical data
	Action	**Automation**: ǀ **Transformation**: This is useful for energy provision and planning.
Type	Presentation	**Cyber**: ǀ
		Physical: x ǀ **Cyber-Physical**:
	Nature	**Electronic-based**: sensor device **Software-based**:
		Human-based: **Non-Human-based**:
	Use	**Wearables**: ǀ **Surroundable**s: sensor devices ǀ **Embeddables**:
	Role	**Sensor**: X ǀ **Actuator**: x
	Engagement	**Opportunistic**: xǀ **Participatory**:
Observation	Location	**Coarse-grained**: Xǀ **Fine-grained**:
	Reach	**Full**: **Partial**: X
	Mobility	**Fixed**: ǀ **Mobile**: X
	Time	**Pull**: ǀ **Push**: X
	Mode	**Sense**: x ǀ **Derive**: X **Manually provided**:
Capabilities	Communication	Pragmatic Communication
	Processing	**Cloud**: X ǀ **Fog/Edge**:
	Storage	**Device-level**: ǀ **Network level** ǀ **Cluster level**: X

Category /Dimension		Characteristic of Energy Usage Recommendations [44]
Knowledge	Explicitness	**Tacit**: ǀ **Explicit**: ǀ **Implicit**: localized smart energy system
	Structure	**Structured, Semi-structured:** data from devices integrating the Digital Home **Unstructured:**
	Trust	**Trustful**: x ǀ **Untrustful**:
	Outcome	**Complements**: ǀ **Substitutes**: performing pattern recognition analysis on accumulated data, spot additional opportunities to save energy
	Action	**Automation**: uses smart plugs and data analysis to actively monitor energy policy ǀ **Transformation**: This is useful for energy provision and planning. reducing the amount of power wasted in non-office hours from appliances, desktops, and printers
Type	Presentation	**Cyber**: ǀ **Physical**: devices integrating the Digital Home ǀ **Cyber-Physical**:
	Nature	**Electronic-based**: devices integrating the Digital Home **Software-based**: **Human-based**: **Non-Human-based**:
	Use	**Wearables**: ǀ **Surroundable**s: ǀ **Embeddables**: devices integrating the Digital Home
	Role	**Sensor**: X ǀ **Actuator**: x
	Engagement	**Opportunistic**: xǀ **Participatory**:
Observation	Location	**Coarse-grained**: ǀ **Fine-grained**: X
	Reach	**Full**: **Partial**: X
	Mobility	**Fixed**: ǀ **Mobile**: X
	Time	**Pull**: X ǀ **Push**:
	Mode	**Sense**: x ǀ **Derive**: X **Manually provided**:
Capabilities	Communication	**Pragmatic Communication**
	Processing	**Cloud**: x ǀ **Fog/Edge**:
	Storage	**Device-level**: ǀ **Network level** ǀ **Cluster level**: x

Category /Dimension		Characteristic of Energy Policy Planning [45]
Knowledge	Explicitness	**Tacit**: ǀ **Explicit**: ǀ **Implicit**: analysis on combined consumption data for use in organizations
	Structure	**Structured, Semi-structured:** detailed appliance-specific data **Unstructured:**
	Trust	**Trustful**: x ǀ **Untrustful**:
	Outcome	**Complements**: ǀ Substitutes: help in energy policy planning.
	Action	**Automation**: **Transformation**: model to classify the energy efficiency of buildings and the seasonal shifts in this classification, and using more, forecasts future energy usage.
Type	Presentation	**Cyber**: ǀ **Physical**: sensor devices ǀ **Cyber-Physical**:
	Nature	**Electronic-based**: sensor devices **Software-based**: **Human-based**: **Non-Human-based**:
	Use	**Wearables**: ǀ **Surroundable**s: ǀ **Embeddables**: sensor devices integrating
	Role	**Sensor**: X ǀ **Actuator**:
	Engagement	**Opportunistic**: xǀ **Participatory**:
Observation	Location	**Coarse-grained**: ǀ **Fine-grained**: X
	Reach	**Full**: **Partial**: X
	Mobility	**Fixed**: ǀ **Mobile**: X
	Time	**Pull**: X ǀ **Push**:
	Mode	**Sense**: x ǀ **Derive**: X **Manually provided**:
Capabilities	Communication	**Pragmatic Communication**
	Processing	**Cloud**: x ǀ **Fog/Edge**:
	Storage	**Device-level**: ǀ **Network level** ǀ **Cluster level**: x

Category /Dimension		Characteristic of Smart Energy System [46]
Knowledge	Explicitness	**Tacit**: ǀ **Explicit**: ǀ **Implicit**: actively monitors implemented policy and constantly perform pattern recognition analysis on accumulated data
	Structure	**Structured, Semi-structured: Unstructured:**
	Trust	**Trustful**: x ǀ **Untrustful**:
	Outcome	**Complements**: unified monitoring across enterprise with energy integration dashboard. ǀ Substitutes:
	Action	**Automation**: allows remote monitoring and control of the appliances connected to smart plugs (intelligent plugs that can measure power usage). **Transformation**:
Type	Presentation	**Cyber**: ǀ **Physical**: sensor devices, Remote end devices (smart-plugs) ǀ **Cyber-Physical**:
	Nature	**Electronic-based**: sensor devices **Software-based**: **Human-based**: **Non-Human-based**:
	Use	**Wearables**: ǀ **Surroundable**s: ǀ **Embeddables**: sensor devices (smart-plugs)
	Role	**Sensor**: X ǀ **Actuator**:
	Engagement	**Opportunistic**: xǀ **Participatory**:
Observation	Location	**Coarse-grained**: ǀ **Fine-grained**: X
	Reach	**Full**: **Partial**: X
	Mobility	**Fixed**: ǀ **Mobile**: X
	Time	**Pull**: X ǀ **Push**:
	Mode	**Sense**: x ǀ **Derive**: X **Manually provided**:
Capabilities	Communication	**Pragmatic communication**
	Processing	**Cloud**: X ǀ **Fog/Edge**:
	Storage	**Device-level**: ǀ **Network level** ǀ **Cluster level**: X

Category /Dimension		Characteristic of On the Shelf Availability [11]
Knowledge	Explicitness	**Tacit**: Shoppers' experience, staff experience ǀ **Explicit**: Enterprise Point of Sale (POS) systems and inventory systems ǀ **Implicit**: algorithm and models from learning systems
	Structure	**Structured**: Data from enterprise ǀ **Semi-structured**: Weather data, local events, and promotion details ǀ **Unstructured**: Real-time data from sensors
	Trust	**Trustful**: Data from enterprise systems ǀ **Untrustful**: Real-time data from shoppers' sensors
	Outcome	**Complements**: Recommended action plans ǀ **Substitutes**: Predictive analytics to provide insights
	Action	**Automation**: stock business processes ǀ **Transformation**: Insights on buyers' behavior
Type	Presentation	**Cyber**: Predictive analytics algorithm ǀ **Physical**: Video cameras, shoppers, the staff of the store, light, infra-red, and RFID sensors ǀ **Cyber-Physical**: Point of Sale (POS) systems
	Nature	**Electronic-based**: video cameras, light, infra-red, and RFID sensors ǀ **Software-based**: Point of Sale (POS) systems ǀ **Human-based**: shoppers, the staff of the store ǀ **Non-Human-based**: shoppers' Pets
	Use	**Wearables**: Shoppers' mobile devices ǀ **Surroundable**s: Video cameras, infra-red sensors ǀ **Embeddables**: Light, RFID sensors
	Role	**Sensor**: Video cameras, light, infra-red, and RFID sensors, shoppers, the staff of the store ǀ **Actuator**: Staff of the store who restock products or actuators to rectify problems ǀ **sensor, and actuato**r: Staff of the store who executes recommended actions
	Engagement	**Opportunistic**: Shoppers ǀ **Participatory**: shoppers/staff of the store
Observation	Location	**Coarse-grained**: supply chain context ǀ **Fine-grained**: Store environment and
	Reach	**Full**: supply chain context **Partial**: Physical Store environment
	Mobility	**Fixed**: inside the store supply chain context ǀ **Mobile**: shoppers mobile devices
	Time	**Pull**: Meta-data produced and sent to the cloud ǀ **Push**: System looks to forecast demands
	Mode	**Sense**: Sensors inside the store ǀ **Derive**: Information derived from weather data ǀ **Manually provided**: data provides from shoppers demand
Capabilities	Communication	**Pragmatic communication** supports the execution of recommended actions **Conceptual communication** provides a novel shopping experience
	Processing	**Cloud**: metadata produced ǀ **Fog/Edge**: Edge: video streams processed locally ǀ **Mobile cloud**: mobile devices from shoppers
	Storage	**Device-level**: Processing video streams locally ǀ **Network level** ǀ **Cluster level**: Metadata produced is sent to the cloud

Category /Dimension		Characteristic of SCM Environ. Control [48]
Knowledge	Explicitness	**Tacit**: ǀ **Explicit**: ǀ **Implicit**: real-time data in analytics in a cold chain monitoring process.
	Structure	**Structured, Semi-structured: Unstructured:**
	Trust	**Trustful**: x ǀ **Untrustful**:
	Outcome	**Complements:** ǀ **Substitutes**: predictions can be made on delays in routes and when necessary to satisfy the product condition needs
	Action	**Automation**: sensors measure the position and conditions in the truck and of each package, while actuators—air conditioning and ventilation—can be controlled automatically. **Transformation**:
Type	Presentation	**Cyber**: ǀ **Physical**: sensor devices, ǀ **Cyber-Physical**:
	Nature	**Electronic-based**: sensor devices **Software-based**: **Human-based**: **Non-Human-based**:
	Use	**Wearables**: ǀ **Surroundable**s: ǀ **Embeddables**: sensor devices
	Role	**Sensor**: X ǀ **Actuator**: X
	Engagement	**Opportunistic**: xǀ **Participatory**:
Observation	Location	**Coarse-grained**: ǀ **Fine-grained**: X
	Reach	**Full**: **Partial**: X
	Mobility	**Fixed**: ǀ **Mobile**: X
	Time	**Pull**: X ǀ **Push**:
	Mode	**Sense**: x ǀ **Derive**: X **Manually provided**:
Capabilities	Communication	Pragmatic Communication
	Processing	**Cloud**: x ǀ **Fog/Edge**:
	Storage	**Device-level**: ǀ **Network level** ǀ **Cluster level**: x

Category /Dimension		Characteristic of SCM 4PL [49] and Floricultural SCM [50]
Knowledge	Explicitness	**Tacit**: ׀ **Explicit**: ׀ **Implicit**:. a virtual supply chain supports intelligent analysis and reporting
	Structure	**Structured, Semi-structured: Unstructured:** big data used in association of cloud computing facilities and the utilization of common (open stated) data format as it is offered by Linked Data for data silos integration purposes.
	Trust	**Trustful**: x ׀ **Untrustful**:
	Outcome	**Complements**:. ׀ Substitutes: X
	Action	**Automation**:. **Transformation**: business intelligence, data mining, and predictive analytics can pro vide early warning in case of disruptions or unexpected deviations and advanced forecasting about consequences of the detected changes when the product reaches destination.
Type	Presentation	**Cyber**: ׀ **Physical**: sensor devices, ׀ **Cyber-Physical**:
	Nature	**Electronic-based**: sensor devices **Software-based**: **Human-based**: **Non-Human-based**:
	Use	**Wearables**: ׀ **Surroundable**s: ׀ **Embeddables**: sensor devices
	Role	**Sensor**: X ׀ **Actuator**:
	Engagement	**Opportunistic**: x׀ **Participatory**:
Observation	Location	**Coarse-grained**: ׀ **Fine-grained**: X
	Reach	**Full**: **Partial**: X
	Mobility	**Fixed**: ׀ **Mobile**: X
	Time	**Pull**: X ׀ **Push**:
	Mode	**Sense**: x ׀ **Derive**: X **Manually provided**:
Capabilities	Communication	Pragmatic Communication
	Processing	**Cloud**: x ׀ **Fog/Edge**:
	Storage	**Device-level**: ׀ **Network level** ׀ **Cluster level**: x

Category /Dimension		Characteristic of Chemical Process Monitoring [52]
Knowledge	Explicitness	**Tacit**: ǀ **Explicit**: ǀ **Implicit**: include linear regression, artificial neural networks (ANN), and Gaussian process regression,
	Structure	**Structured, Semi-structured: Unstructured:** predict variables using available process data
	Trust	**Trustful:** x	**Untrustful**:
	Outcome	**Complements**:. ǀ **Substitutes**: These predictions enable quality monitoring and advance control systems in plants
	Action	**Automation**: automatically react to prevent off-grade products. **Transformation**: prescribe process modifications
Type	Presentation	**Cyber**: ǀ **Physical**: sensor ǀ **Cyber-Physical**: inferential industrial IoT sensors to process monitoring chains
	Nature	**Electronic-based**: inferential industrial IoT sensors to process monitoring chains **Software-based**: **Human-based**: **Non-Human-based**:
	Use	**Wearables**: ǀ **Surroundable**s: ǀ **Embeddables**: sensor devices
	Role	**Sensor**: X ǀ **Actuator**:
	Engagement	**Opportunistic**: xǀ **Participatory**:
Observation	Location	**Coarse-grained**: ǀ **Fine-grained**: X
	Reach	**Full**: **Partial**: X
	Mobility	**Fixed**: ǀ **Mobile**: X
	Time	**Pull**: X ǀ **Push**:
	Mode	**Sense**: x ǀ **Derive**: X **Manually provided**:
Capabilities	Communication	**Pragmatic Comunication**
	Processing	**Cloud**: x ǀ **Fog/Edge**:
	Storage	**Device-level**: ǀ **Network level** ǀ **Cluster level**: x

Category /Dimension		Characteristic of Smart Farming [51]
Knowledge	Explicitness	**Tacit**: ׀ **Explicit**: ׀ **Implicit**: Complex Event Processing (CEP)
	Structure	**Structured, Semi-structured: Unstructured:** semantically enriched data streams from sensors
	Trust	**Trustful**: x ׀ **Untrustful**:
	Outcome	**Complements**: discover significant events on semantically enriched data streams from sensors. ׀ Substitutes:
	Action	**Automation: Transformation**: detecting the fertility of cows from temperature readings and adaptively control the soil conditions for crop cultivation.
Type	Presentation	**Cyber**: ׀
		Physical: sensor devices׀ **Cyber-Physical**:
	Nature	**Electronic-based**: sensor devices **Software-based**:
		Human-based: **Non-Human-based**:
	Use	**Wearables**: ׀ **Surroundable**s: ׀ **Embeddables**: sensor devices
	Role	**Sensor**: X ׀ **Actuator**:
	Engagement	**Opportunistic**: x׀ **Participatory**:
Observation	Location	**Coarse-grained**: ׀ **Fine-grained**: X
	Reach	**Full**: **Partial**: X
	Mobility	**Fixed**: ׀ **Mobile**: X
	Time	**Pull**: X ׀ **Push**:
	Mode	**Sense**: x ׀ **Derive**: X **Manually provided**:
Capabilities	Communication	Pragmatic Communication
	Processing	**Cloud**: x ׀ **Fog/Edge**:
	Storage	**Device-level**: ׀ **Network level** ׀ **Cluster level**: x

Category /Dimension		Characteristic of health care industry [12]
Knowledge	Explicitness	**Tacit**: humans ǀ **Explicit**: real-time media data ǀ **Implicit**: robots
	Structure	**Structured, Semi-structured:** real-time media data **Unstructured:** real-time media data
	Trust	**Trustful**: x ǀ **Untrustful**:
	Outcome	**Complements**: The prognosis and diagnostic process will become highly structured due to CPS and decisions taken, will be based on evidence supported results and treatments. ǀ **Substitutes**:
	Action	**Automation:** robots taking over smartly, surgical procedures **Transformation**: human enhancement will experience reduced errors. .
Type	Presentation	**Cyber**: ǀ **Physical**: sensor devices ǀ **Cyber-Physical**: robots
	Nature	**Electronic-based**: robots| **Software-based**: **Human-based**: patients, doctors**Non-Human-based**:
	Use	**Wearables**: medical sensors devices ǀ **Surroundable**s: ǀ **Embeddables**:
	Role	**Sensor**: X ǀ **Actuator**: x
	Engagement	**Opportunistic**: X| **Participatory**:
Observation	Location	**Coarse-grained**: ǀ **Fine-grained**: X
	Reach	**Full**: **Partial**: X
	Mobility	**Fixed**: ǀ **Mobile**: X
	Time	**Pull**: X ǀ **Push**:
	Mode	**Sense**: x ǀ **Derive**: X **Manually provided**:
Capabilities	Communication	**Conceptual Communication**
	Processing	**Cloud**: x ǀ **Fog/Edge**:X
	Storage	**Device-level**: ǀ **Network level** ǀ **Cluster level**: x

Category /Dimension		Characteristic of Agriculture [12]
Knowledge	Explicitness	**Tacit**: engineers ǀ **Explicit**: data on accurate farming ǀ **Implicit**: IA
	Structure	**Structured, Semi-structured:** **Unstructured:** data on accurate farming
	Trust	**Trustful**: x ǀ **Untrustful**:
	Outcome	**Complements**: ǀ **Substitutes**: link information gathered from food production processes and package development to devices such as refrigerators
	Action	**Automation:** technologies will replace human workers. **Transformation**: . But in the context of Industry 4.0, robots will require highly trained, and skilled engineers to manage robots
Type	Presentation	**Cyber**: ǀ **Physical**: farming machines ǀ **Cyber-Physical**: food sensors and drones
	Nature	**Electronic-based**: food sensors, sensors, farming machines and drones **| Software-based**: **Human-based**: **Non-Human-based**:
	Use	**Wearables**: ǀ **Surroundable**s: ǀ **Embeddables**: food sensors
	Role	**Sensor**: x ǀ **Actuator**:
	Engagement	**Opportunistic**: xǀ **Participatory**:
Observation	Location	**Coarse-grained**: ǀ **Fine-grained**: X
	Reach	**Full**: **Partial**: X
	Mobility	**Fixed**: ǀ **Mobile**: X
	Time	**Pull**: X ǀ **Push**:
	Mode	**Sense**: x ǀ **Derive**: X **Manually provided**:
Capabilities	Communication	Pragmatic Communication / link information gathered from food production processes and package development to devices such as refrigerators.
	Processing	**Cloud**: X ǀ **Fog/Edge**:
	Storage	**Device-level**: ǀ **Network level** ǀ **Cluster level**: X

Category /Dimension		Characteristic of Manufacturing [12]
Knowledge	Explicitness	**Tacit**: There will be a likely increase on acquiring digital skills| **Explicit**: | **Implicit**: intelligent machines
	Structure	**Structured, Semi-structured: Unstructured:** data as an asset to support the evolution radical manufacturing processes
	Trust	**Trustful**: | **Untrustful**:
	Outcome	**Complements**: | Substitutes: in the field of nanotechnology,
	Action	**Automation: Transformation**: structural changes to conventional processes that are followed, giving full throttle rise to the 4th Industrial revolution, Industry 4.0..
Type	Presentation	**Cyber**: | **Physical**: layman | **Cyber-Physical**: sensor devices
	Nature	**Electronic-based**: sensor devices **| Software-based**: **Human-based**: **Non-Human-based**:
	Use	**Wearables**: | **Surroundable**s: | **Embeddables**: miniaturization of actuators and sensors
	Role	**Sensor**: x | **Actuator**:
	Engagement	**Opportunistic**: x | **Participatory**:
Observation	Location	**Coarse-grained**: | **Fine-grained**: X
	Reach	**Full**: **Partial**: X
	Mobility	**Fixed**: | **Mobile**: X
	Time	**Pull**: X | **Push**:
	Mode	**Sense**: x | **Derive**: X **Manually provided**:
Capabilities	Communication	**Pragmatic Communication**
	Processing	**Cloud**: X | **Fog/Edge**:
	Storage	**Device-level**: | **Network level** | **Cluster level**: x

Category /Dimension		Characteristic of Energy and Critical Infrastructure[12]
Knowledge	Explicitness	**Tacit**: humans with digital skills| **Explicit**: | **Implicit**: intelligent grids via the "IoE-Energy Internet
	Structure	**Structured, Semi-structured: Unstructured:** continuous live-data to producers and consumers
	Trust	**Trustful**: X | **Untrustful**:
	Outcome	**Complements**: | Substitutes: future energy systems will become a global Internet of Energy.
	Action	**Automation**: controlling electricity flow from producers to end-users or consumers. **Transformation**: The transition will result in "energy prosumers'—individuals that will consume and produce energy.
Type	Presentation	**Cyber**: | **Physical**: | **Cyber-Physical**: Smart grids
	Nature	**Electronic-based**: Smart grids **| Software-based**: **Human-based**: **Non-Human-based**:
	Use	**Wearables**: | **Surroundable**s: Smart grids| **Embeddables**:
	Role	**Sensor**: Smart grids | **Actuator**:
	Engagement	**Opportunistic**: X| **Participatory**: x
Observation	Location	**Coarse-grained**: | **Fine-grained**: X
	Reach	**Full**: **Partial**: X
	Mobility	**Fixed**: | **Mobile**: X
	Time	**Pull**: X | **Push**:
	Mode	**Sense**: x | **Derive**: X **Manually provided**:
Capabilities	Communication	**4 -**
	Processing	**Cloud**: x | **Fog/Edge**:
	Storage	**Device-level**: | **Network level** | **Cluster level**: x

Category /Dimension		Characteristic of Logistics and Transport: [12]
Knowledge	Explicitness	**Tacit**: ׀ **Explicit**: ׀ **Implicit**: robotic handling systems
	Structure	**Structured, Semi-structured: Unstructured:** real-time informations
	Trust	**Trustful**: x ׀ **Untrustful**:
	Outcome	**Complements**: ׀ **Substitutes**: deployment of completely autonomous fleets in transportation and logistics sectors will be a reality
	Action	**Automation:** Automobiles are automated and advanced driver assistance systems that will make cars smarter by providing automated assistance. **Transformation**: reduction in emissions and efficiency optimization to achieve higher saving in fuel consumption.
Type	Presentation	**Cyber**: ׀ **Physical**: sensor devices in urban areas׀ **Cyber-Physical**:
	Nature	**Electronic-based**:x **׀ Software-based**: **Human-based**:xx **Non-Human-based**:
	Use	**Wearables**: ׀ **Surroundable**s: X ׀ **Embeddables**:
	Role	**Sensor**: X ׀ **Actuator**: x
	Engagement	**Opportunistic**: x׀ **Participatory**:
Observation	Location	**Coarse-grained**: ׀ **Fine-grained**: X
	Reach	**Full**: **Partial**: X
	Mobility	**Fixed**: ׀ **Mobile**: X
	Time	**Pull**: X ׀ **Push**:
	Mode	**Sense**: x ׀ **Derive**: X **Manually provided**:
Capabilities	Communication	Pragmatic Communication -
	Processing	**Cloud**: X ׀ **Fog/Edge**:
	Storage	**Device-level**: ׀ **Network level** ׀ **Cluster level**: X

Category /Dimension		Characteristic of Security and Safety: [12]
Knowledge	Explicitness	**Tacit**: humans with specialized skills| **Explicit**: x | **Implicit**:x
	Structure	**Structured, Semi-structured: Unstructured:** data from potential threats
	Trust	**Trustful**: | **Untrustful**: challenges for security and safety
	Outcome	**Complements**: handling data from potential threats will require specialized skills. | Substitutes:
	Action	**Automation: Transformation**: highly complex environment that would require improved understanding of machines and their effects on security safety measures.
Type	Presentation	**Cyber**: | **Physical**: x | **Cyber-Physical**: x
	Nature	**Electronic-based**: x **| Software-based**: **Human-based**: x **Non-Human-based**:
	Use	**Wearables**: | **Surroundable**s: | **Embeddables**: X
	Role	**Sensor**: X | **Actuator**:
	Engagement	**Opportunistic**: X| **Participatory**:
Observation	Location	**Coarse-grained :** X | **Fine-grained**:
	Reach	**Full**: **Partial**: X
	Mobility	**Fixed**: | **Mobile**: X
	Time	**Pull**: X | **Push**:
	Mode	**Sense**: x | **Derive**: X **Manually provided**:
Capabilities	Communication	Pragmatic Communication
	Processing	**Cloud**: X | **Fog/Edge**:
	Storage	**Device-level**: | **Network level** | **Cluster level**: x

Category /Dimension		Characteristic of Smart home [12]
Knowledge	Explicitness	**Tacit**: humans ǀ **Explicit**: ǀ **Implicit**: Smart home assistants
	Structure	**Structured, Semi-structured:** **Unstructured:** real-time big data (Especially, unstructured and semi structured data)
	Trust	**Trustful**: X ǀ **Untrustful**:
	Outcome	**Complements**: X ǀ Substitutes:
	Action	**Automation: specialized task-oriented robots Transformation**: internet enabled devices to remotely monitor and control applications
Type	Presentation	**Cyber**: ǀ **Physical**: x ǀ **Cyber-Physical**: wearable sensors and robotics
	Nature	**Electronic-based**: sensors for disabled and eldering people **ǀ Software-based**: **Human-based**: x **Non-Human-based**:
	Use	**Wearables**: wearable sensors ǀ **Surroundable**s: ǀ **Embeddables**: robotics
	Role	**Sensor**: X ǀ **Actuator**: controlling of electronic devices and other home appliances
	Engagement	**Opportunistic**: Xǀ **Participatory**:
Observation	Location	**Coarse-grained:** X ǀ **Fine-grained**:
	Reach	**Full**: **Partial**: X
	Mobility	**Fixed**: ǀ **Mobile**: X
	Time	**Pull**: X ǀ **Push**:
	Mode	**Sense**: x ǀ **Derive**: X **Manually provided**:
Capabilities	Communication	Pragmatic Communication
	Processing	**Cloud**: cloud services ǀ **Fog/Edge**: chips and sensors store a huge amount of data and information
	Storage	**Device-level**: chips and sensors store a huge amount of data and information ǀ **Network level** ǀ **Cluster level**: cloud services x

Category /Dimension		Characteristic of Environment Observation [12]
Knowledge	Explicitness	**Tacit**: scientists ǀ **Explicit**: ǀ **Implicit**: X
	Structure	**Structured, Semi-structured: Unstructured:** real-time big data (Especially, unstructured and semi structured data)
	Trust	**Trustful**: X ǀ **Untrustful**:
	Outcome	**Complements**: gathered data can later be transmitted to research labs ǀ **Substitutes**:
	Action	**Automation: specialized task-oriented robots Transformation**: application in observing and studying the behavior of changing environment
Type	Presentation	**Cyber**: ǀ **Physical**: x ǀ **Cyber-Physical**: deployed sensors
	Nature	**Electronic-based**: deployed sensors **| Software-based**: **Human-based**: x **Non-Human-based**:
	Use	**Wearables**: ǀ **Surroundable**s: deployed sensors ǀ **Embeddables**:
	Role	**Sensor**: X ǀ **Actuator**:
	Engagement	**Opportunistic**: Xǀ **Participatory**:
Observation	Location	**Coarse-grained:** X ǀ **Fine-grained**:
	Reach	**Full**: **Partial**: X
	Mobility	**Fixed**: ǀ **Mobile**: X
	Time	**Pull**: X ǀ **Push**:
	Mode	**Sense**: x ǀ **Derive**: X **Manually provided**:
Capabilities	Communication	Pragmatic Communication
	Processing	**Cloud**: cloud services ǀ **Fog/Edge**:
	Storage	**Device-level**: ǀ **Network level** ǀ **Cluster level**: cloud services x

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