# Smart university: the sustainable vector of knowledge

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**ABSTRACT.** The term smart has been increasingly used to refer to a process of rethinking and modernization in different areas and contexts, covering the use of innovative technology solutions, sharing networks and data, and access to goods and services. That's all feasible thanks to multi-stakeholder participation at different levels, and access through the use of ICT. In the definition adopted in January 2014, the Committee on Industry, Research and Energy (ITRE) Committee of the European Parliament, has defined a Smart City as "a city seeking to address public issues via ICT based solutions on the basis of a multi-stakeholder, municipally based partnership". That definition is lacking of a crucial concept. It is scientifically incorrect to define "smart" any human expression in perspective without referring to sustainability. Smart means, therefore, sustainable. This work highlights the close link between smart university and sustainability. In a parallel with smart grids, smart mobility, and Smart Cities, university, through the smartification of its essential components can be much more sustainable when evolved into a distance learning, networked and connected smart university compared to "traditional" fully physical university. Smart university shares physical elements, needs and moves less mass, being in one word, more efficient. As well as from the energy point of view, a sustainable future can be defined as the "Era of energy vectors" in which "an energy vector allows transfer, in space and time, a given quantity of energy, hence making it available for use distantly in time and space from the point of availability of the original source", from a knowledge point of view, smart university allows to transfer, in space and time, a given knowledge, hence making it available for use distantly in time and space from the point of availability of the original source. The aim of developing a sustainable society is a very strong driver towards the smartification of education and research, and the Smart university considered as a sustainable vector of knowledge is the key factor for its realization.

***KEYWORDS:*** *Smart city, Smart university, Sustainability, Vectors*

## Introduction: the Smart City

### *Characterization of a Smart City*
### *Smart City definition*

In January 2014, the Commission ITRE – Industry, Research and Energy, of the European Parliament, published a study entitled "Mapping Smart Cities in EU", in which it proposes, in addition to a detailed mapping of the main European Smart Cities, a broad spectrum analysis on the state of the art.
Another key aspect of this study is the attempt to give, through the analysis and mapping of European Smart Cities, a standard definition of intelligent city, a shared model of Smart City and specific guidelines for the design and construction of Smart Cities or parts of them.
From the point of view of the definitions of a Smart City, there are different versions, but the definition adopted in the last study of the ITRE Committee is: "a city seeking to address public issues via ICT-based solutions on the basis of a multi-stakeholder, municipally based partnership" (EU, 2014, p. 9).

### *The six Smart City characteristics*

The Smart City sees as the cornerstone of its existence the "coexistence" between human capital, social capital and ICT infrastructure, ensuring greater and more sustainable economic development and a better quality of life.

A city, to be classified as a Smart City, must have at least an initiative which addresses one or more of the six characteristics.

1. Smart governance
2. Smart economy
3. Smart mobility
4. Smart environment
5. Smart people
6. Smart living

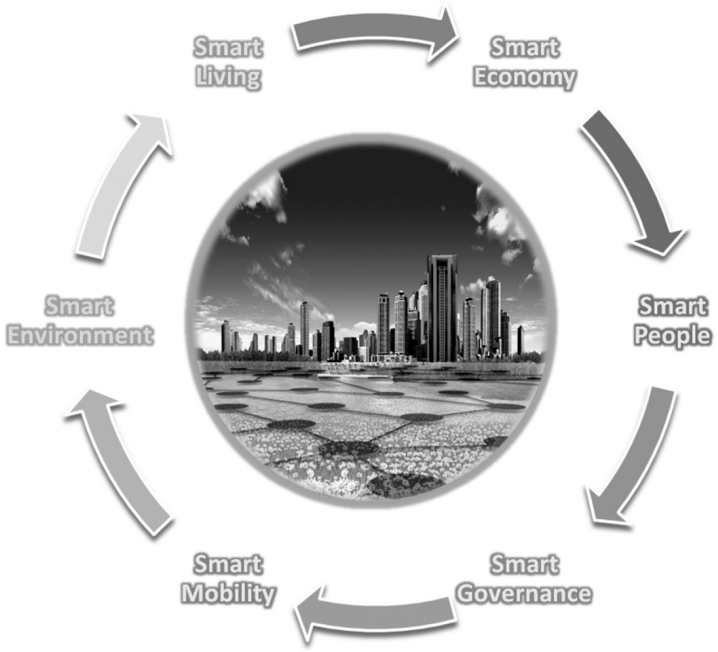


**Figure 1**. The six Smart City characteristics

*1. Smart governance*

Smart governance requires an administration that, in a long-term strategic vision, coordinates and manages the development plan and processing into a Smart City, considering public, private and civil partnerships, to ensure an efficient and effective operation of the city. ICT (infrastructures, hardware and software) is the main tool that achieves this objective, enabled by smart processes and interoperability and powered by the data. Specifically the smart objectives of smart governance include the transparent functioning of the administration systems with open data through the use of ICT, the participation of citizens in the process of decision-making and the "co-creation" of e-services, such as apps (applications). This implies, as already mentioned, partnerships of public, private and civil society and collaboration with different stakeholders working together in pursuit of the objectives of a Smart City with shared solutions.

At the national level, and with the goal of smart governance, local governments should concentrate first of all on administrative simplification and digitalization of processes and procedures.

In general, Smart Governance can be viewed as an absolutely transversal factor and as such, this kind of governance can also control and integrate some or all of the other five smart characteristics. The main features of smart governance, declinable under the concept of "participation" are (Giffinger et al., 2007):

- participation in decision-making
- public and social services
- transparent governance
- political strategies & perspectives.

*2. Smart economy*

A smart economy requires the adoption of e-business and e-commerce with ICT-enabled systems. Furthermore, in this field the investments aim for research and innovation, thus favoring those processes of internationalization, the sharing of knowledge and enhancement of creativity. If you want to control the process of transformation of our cities into a Smart City – with the promotion of a synergistic system of private enterprise, government agencies, research institutes all joined in raising the technological level and able to stimulate as many businesses as each citizen – you need to invest in the knowledge economy.

In general, the main features of a smart economy, declinable under the concept of "competitiveness" are (Giffinger et al., 2007):

- innovative spirit
- entrepreneurship
- economic image & trademarks
- productivity
- flexibility of labour market
- international embeddedness
- ability to transform.

*3. Smart mobility*

Smart mobility requires a set of transport and logistic systems supported and integrated by ICT. For example, sustainable transport systems – safe and interconnected – may include trams, buses, trains, subways, cars, motorbikes, bicycles and moving pedestrians in which one or more modes of transport can be used.

Smart mobility is oriented primarily towards clean and often non-motorized solutions. Relevant information can be accessible to the public in real time to save time, improve the efficiency of commuting, reduce costs and CO2 emissions, as well as improve services and provide citizen feedback to the operators of the transport network. The users of the mobility system may also provide their data in real time or contribute to long-term planning.

It should be noted that the constant growth of mobility in recent years (six-fold increase over the last forty years, doubled in the last decade cfr. La Rocca, 2011) derives from population growth, globalization and urbanization: the number of people and assets in movement grows and frequency and distances increase more and more. Consequently, intelligent management systems for mobility are no longer an option but a requirement.

In general, the main features of smart mobility, declinable under the concept of "transport and ICT" are (Giffinger et al., 2007):

- local accessibility
- (inter-)national accessibility
- availability of ICT-infrastructure
- sustainable, innovative and safe transport systems.

*4. Smart environment*

A smart environment includes smart energy (Orecchini, Santiangeli, 2011), and therefore also

renewable energy, ICT enablement of energy networks, measurement systems, control systems and pollution monitoring, restructuring and rationalization of construction, protection and management of urban greenery and the remediation of brownfield sites, as well as energy efficiency and environmental sustainability, recycling and reuse initiatives, public street lighting, drainage systems and water systems.

In general, the main features of a smart environment, declinable under the concept of "natural resources" are (Giffinger et al., 2007):

- attractivity of natural conditions
- pollution
- environmental protection
- sustainable resource management.

*5. Smart people*

Smart people means people with computer skills, ICT experts, people who have access to education and training, human resources and capacity management within an inclusive society that enhances the creativity of citizens, experts and activists, encouraging innovation and interactivity by shared efforts. This can also allow people and communities to enter, use, develop and customize their own data made available, for example, through appropriate data analysis tools and on board control panels to make decisions and create products and services.

It is possible to say that it is the "people" towards which the administration should pay utmost attention, accepting and responding to the challenge to intercept, connect and join the initiatives of social innovation, discovering and practicing their management and support prerogatives.

In general, the main features of smart people, declinable under the concept of "social and human capital" are (Giffinger et al., 2007):

- level of qualification
- affinity to lifelong learning
- social and ethnic plurality
- flexibility
- creativity
- cosmopolitanism/openmindedness
- participation in public life.

*6. Smart living*

Smart living means lifestyle, behaviour and consumption based on ICT.

Smart living is also living in health and safety in a culturally vibrant city with various cultural facilities, including housing and good quality accommodation. Smart living is also linked to high levels of social cohesion and social capital.

Smart living must surely derive from respect of its history and identity, projecting a vision of Smart City, with the promotion of its tourist image, through innovative tools such as intelligent presence on the web and virtualization of their cultural heritage and traditions. This means to network a "common benefit" for its citizens and its visitors with tours and easy-to-use "mapping" issues of the city.

In general, the main features of smart living, declined under the concept of "quality of life" are (Giffinger et al., 2007):

- cultural facilities
- health conditions
- individual safety
- housing quality
- education facilities
- tourist attractivity
- social cohesion.

### *Smart City components*

The six characteristics described above, which include the areas addressed by Smart City initiatives and which illustrate the variety of Smart City projects in all EU Member States, are used to classify a Smart City.
These features are, in short, the objectives to which stakeholders contribute in an initiative. The study "Mapping Smart Cities in EU" defines the means by which these objectives are achieved with the term "components". If, for example, the characteristic of an initiative is the smart environment, the components can be the various environmental technologies.
The term "component" covers a wide range of activities, resources and methods; some are pre-existing, while others are created for specific projects.
The components, which can be conceptualized as the "building blocks" of Smart City initiatives, include inputs, technologies, processes for specific initiatives and the rules or standards used.
In assessing the relationship between components and characteristics of the Smart City, some intellectuals argue that the components can be freely stratified by the six characteristics, which in turn are used to identify whether a city is "smart". Some intellectuals see the components of a Smart City as drivers of specific characteristics, based on the specific needs and challenges that the city faces on the basis of that characteristic (Orecchini, Santiangeli, 2011). In fact, in many situations, it is noted that, while some components belong to a specific characteristic (for example, "green buildings" and "energy sensor", which are specific to the characteristic "smart environment"), others are horizontal or enabler (e.g. open data and monitoring technologies) and cover different characteristics.
With a holistic approach, some intellectuals classify the components on three main factors (Cohen, 2012):

- technology factors
  - physical infrastructure
  - smart technologies
  - mobile technologies
  - virtual technologies
  - digital networks
- human factors
  - human infrastructure
  - social capital

- institutional factors
  - governance
  - policy
  - regulations and directives

The relationship between components and characteristics is complex: on the one hand the availability of existing components in a city can make the development of Smart City initiatives easier; on the other hand, the components can be considered, instead, as desired or necessary by products of such initiatives, insofar as they are developed or improved during the course of the initiatives.
In figure 2 a schematic of relationship between components (outer ring) and characteristics (inner ring) is shown.

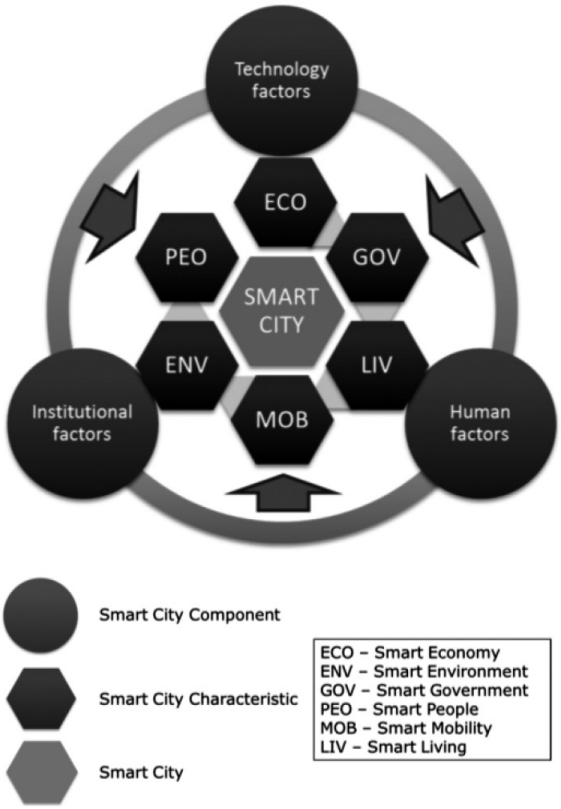


**Figure 2**. Relationship between components and characteristics of a Smart City

## Smart university: telematic university and Smart City

### *The e-learning and telematic university*

Compared to the traditional university, e-learning and telematic universities have special characteristics that make them "smarter". The main ones are the high energy efficiency and high flexibility in service provision.

*Energy efficiency of e-learning and telematic universities*

Energy efficiency can be generally defined as the energy spent to achieve a given effect, such as a product or service production. In regards to university, in particular to teaching, it is possible to assess the energy consumption per student enrolled[1].
With regard to energy consumption, for a correct evaluation of efficiency a "well to use" approach it is necessary, that considers not only the energy consumption of the university (as a physical structure) but the entire energy process. Similar to the "well to wheel" analysis of traction systems in which, in addition to "in the car" consumption (tank to wheel) even "out of the car" (well to tank) is considered as well (i.e. those due to production, storage, transport and distribution of the energy vector used), with regards to universities, in addition to "inside the university", that due to the mobility of people (students, professors, researchers, administration personnel) is considered as well.
Considering the given definitions, a high energy efficiency of telematic universities can be easily noted, due to the substantial reduction of "energy demand" per enrolled student compared to traditional universities. This reduction is mainly due to the following factors.

- Reduction of consumption "outside the university": this reduction is mainly due to the reduction of the students' mobility; most of the mobility of students in traditional universities is due to the attendance to class lessons. The telematic university substantially reduces the mobility of students. Widespread e-learning and e-work (even beyond the university) can have appreciable effects, induced in terms of traffic congestion reduction in urban centers with a consequent reduction in fuel consumption and emissions for urban mobility.
- Reduction of consumption "in the university": the telematic university allows a substantial reduction of the energy requirements for courses. The consumption in traditional universities is largely due to heating/cooling, lighting, etc. of the classrooms.

*Flexibility of e-learning and telematic universities*
The telematic university, as opposed to the traditional one, is extremely flexible because the use of the service (teaching) is not subject to any restrictions of time and place, or rather the student can use the service when he wants and where he wants.
Being online, the video lessons – in addition to the all the paperwork (booking exams, etc.) – can be done at any time of the day (even at night) any day of the week (including holidays) from any place the student is found. This latter feature has become particularly important in recent years with the growth of communication technologies (laptops, tablets, smartphones, etc.) and availability of 3G and 4G networks (in the territory). In fact, today thanks to these communication technologies, the sentence "I can study at any place" refers no more to a place, however close and convenient to the student, which must in any case be provided with specific technologies (eg: a place like a room equipped necessarily with a PC, LAN etc...) but can literally mean a place that is really "a whichever place" (eg: at the bus stop using a smartphone, by the train using a tablet,...). In addition, students can

1 In literature there are several parameters, depending on the specific application, linked in some way to the general concept of energy efficiency; in transformation and conversion energy plants, efficiency is the ratio of useful energy produced and energy consumed. In the (macro) economic analysis, efficiency is expressed through the energy intensity (for example of a country or an economic sector) which expresses the ratio between the energy consumed and the GDP (Gross Domestic Product) of the country or the specific economic sector.

visualize the same lesson (or part of it) as much as necessary for understanding.
A service provided to the typical online student is tutoring (a tutor is assigned a specific course of instruction) which, thanks to the telematic tools these universities have, is available to the student without the constraints due to the frontal tutoring which considers a "physical" meeting (not virtual), in a certain place (the university) and at a given time. The advantage for the student is that the assistance is free of the constraints of times (office hours) or duration and the student may have "virtually unlimited" assistance. A standard operating medium provides the tutor's answer within 24 hours of the question asked by the student. Another important feature of the telematic university is the usability that allows the remote (avoiding commuting) university access to people living in a city where the university itself is not present.
The mentioned features shall ensure that the telematic university allow access to higher education to many people who have constraints incompatible with the commitments "scheduled to run", tied to places, dates and times, required traditional universities. In particular the telematic university provides access to higher education for people – those beyond the "standard" university age range (over 30 years), married, with children, workers and residents in the city.

*E-learning and learning with traditional lessons*
The features described in the previous paragraphs are not obviously discriminatory for those who have no particular impediments of time and place. This means that, on the one hand, a person who was unable to enroll in a traditional university could do so at a telematic one for the above features, and on the other, a person who could enroll in a traditional university could easily do so at a telematic one.
One of the criticisms that is usually directed to telematic lessons, in comparison with traditional ones, is that if distance teaching is plausible for the humanistic disciplines, it is not so for the scientific ones due to the lack of time spent on practical activities such as in laboratory. This assertion can be refuted in two ways: a telematic university can acquire real laboratories, to be scheduled just like traditional universities; or technological innovations of virtual reality can realize levels of simulation that, in a sensitive area such as the surgical setting, virtual reality tools allow you to try again and again a delicate operation such as that involving the brain before moving the patient, ensuring maximum safety with minimum risk in patient interventions. These simulators are based on experiences in the field of aeronautics.

## E-learning in the Smart City vision

A city, to be classified as a Smart City, must have at least an initiative which addresses one or more of the six characteristics described in the "Six Smart City characteristics" paragraph.
Due to its characteristics, the telematic university can help to address and improve all the features mentioned. Shown below is the contribution of the telematic university for every single characteristic of the Smart City.

***Smart governance***

The opportunity to access university studies for a large population of groups otherwise unable represents an improvement of usability of public and social services.

*Smart economy*

The telematic university, being based on platforms and then continuously evolving technologies, has a particular propensity to continuous innovation from the point of view of the technologies used (development of new platforms with innovative technologies) and in the manner and within the content of the educational service disbursed.
The absence of classroom lectures allows teachers to be able to follow more courses and have more time to research, update. In addition, the online delivery, in addition to lectures, of all other ancillary services (booking exams, registration, etc.) allows for the optimization of the non-teaching staff (administrative) carrying out such services. These characteristics mean that the telematic university is highly productive.
The teaching mode of the lessons and services in general makes them immediately (after translation) usable in various countries which makes the telematic university particularly suited to an international setting.
The virtual structure gives the telematic university a high capacity to transform itself.

*Smart mobility*

The reduction in displacements can help achieve sustainable, innovative and safe transport systems (Orecchini, Santiangeli, Valitutti, 2011) as an induced effect of the decongestion of traffic.

*Smart environment*

The reduction of energy requirements decreases pollution, contributing to the protection of the environment and a sustainable management of resources (resource savings).

*Smart people*

The opportunity to access university studies for a large population of groups, otherwise unable, may contribute to the growth of the level of qualification, and the education methods (e-learning) available to the users (students) may contribute to giving them a real possibility for lifelong learning.

*Smart living*

The aforementioned capabilities of the telematic university to offer the possibility to access university studies for a large population of groups, otherwise unable represent a potential improvement of facilities for education.

## Sustainability of e-learning university as a vector of knowledge

From the energy point of view, a sustainable future can be defined as the "era of energy vectors" (based on locally available resources and needs), in which "an energy vector allows the transfer, in space and time, of a given quantity of energy, hence making it available for use distantly in time and space from the point of availability of the original source" (Orecchini, Naso, 2011). In similar manner, from a point of view of the knowledge, a smart university allows to transfer, in space and time, a specific knowledge of a certain argument (e.g.: a lesson of a specific professor), hence making it available for its learning distantly in time and space from the point of availability of the original source (continuing from the previous example: the "point" in which the professor has performed its

lesson). A university in which the only way to attend to a certain lesson of a specific professor is to be in the place and at the time in which the professor performs his lesson (frontal lesson), is not a vector of knowledge.
The aim of developing a sustainable society is a very strong driver towards the smartification of education and research, and the smart university considered as a sustainable vector of knowledge is the key factor for its realization.
With this analogy between energy vectors and the vector of knowledge, to evaluate the sustainability of the telematic university as a vector of knowledge you may refer to the pillars of sustainable energy, among which we find (Orecchini, 2011 and 2007):

- efficiency
- environmental impact
- accessibility.

From the foregoing in the previous paragraphs, it is evident how the vector of knowledge "telematic university" presents the characteristics of sustainability: it is extremely efficient and with a low environmental impact and accessible to a large segment of the population in comparison to a "traditional university".

## Conclusions

The characteristics of the telematic university are, far more than the traditional ones, in line with the characteristics of the Smart City as well as with the sustainability criteria.
Regarding the Smart City, the characteristics of the telematic university exposed are in line with the objectives of the strategic vision of Europe 2020 , in particular those concerning climate change (reduction of emissions of greenhouse gases 20%, or even 30% if the conditions allow it, compared to 1990 and 20% increase in energy efficiency) education (increase of 40% of people over 34 years with a university education) (Orecchini et al. 2014).
On the other hand, the particularities of the telematic university that set it apart from traditional ones do not have undesirable effects, meaning that the improvement of certain characteristics (efficiency, flexibility) does not affect others; in other words the telematic university can be thought as an evolution of the traditional ones, more flexible and efficient.

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## Sintesi

*La Smart City, "una città che cerca di affrontare questioni di pubblico interesse attraverso soluzioni di ICT, sulla base di partnership municipali multi-stakeholder", vede quale caposaldo della sua stessa esistenza la "convivenza" tra capitale umano, capitale sociale e infrastrutture ICT. Il suo obiettivo è garantire un maggiore e più sostenibile sviluppo economico per una migliore qualità della vita. Per essere classificata tale, la Smart City deve avere almeno un'iniziativa in una o più delle seguenti sei caratteristiche: Smart Governance, Smart Economy, Smart Mobility, Smart Environment, Smart People, Smart Living.*

*A partire da queste peculiarità, l'articolo vuole offrire elementi di valutazione del grado di smartness di un'università, perché essa possa definirsi Smart University. L'articolo vuole anche dimostrare come le qualità dell'università telematica siano in linea sia con le caratteristiche della Smart City e, quindi, della Smart University, sia con i criteri di sostenibilità (Efficienza, Impatto ambientale ed Accessibilità); tali proprietà assegnano alle università telematiche, rispetto alle università tradizionali, una più elevata efficienza energetica ed una maggiore flessibilità nella fornitura dei servizi.*

*Così, come dal punto di vista energetico un futuro sostenibile può essere definito come "l'era dei vettori energetici", in cui "un vettore energetico consente di veicolare, nello spazio e nel tempo, una determinata quantità di energia, rendendola disponibile a distanza di tempo e di spazio", in modo simile, dal punto di vista della conoscenza, un'università Intelligente consente di veicolare nello spazio e nel tempo, una determinata conoscenza, rendendola disponibile per un apprendimento a distanza. Un'università, in cui l'unico modo per gli studenti di partecipare ad una specifica lezione è quello di essere nel posto e nel momento stesso in cui il professore svolge la lezione (lezione frontale), non è un vettore di conoscenza.*

*L'obiettivo di sviluppare una società sostenibile è un incentivo determinante come traino verso la smartificazione dell'istruzione e della ricerca, e l'università intelligente considerata come vettore sostenibile della conoscenza è il fattore chiave per la sua realizzazione.*