Title: The alignment of University curricula with the building of a Smart City: A case study from Barcelona.

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Abstract:

This paper argues the role of the University in the Smart City transformation strategy. The theoretical structure takes as reference the recent Complexity theory for city development and their application to the networks of the Connected city. The approach is based on a justified selection of Barcelona and its four universities. We carry out a deductive and interpretivist method interviewing 19 senior experts whole profiles represent the different forces of the Triple Helix model. Our results show the Barcelona city hall has the objective to implement five main innovative services which are fuelled by six main emerging technologies. Nevertheless, we demonstrate that the universities curriculum is not aligned with the city hall's objectives and a gap exists to prepare the undergraduates to the professions required for the Smart City. We recommend six propositions to reshape the University program curricula and leverage the application of Complexity theory to network. The originality of this study is to propose a 3-phases method along with a framework with pre-filled templates and protocols of interviews to analyze universities that pursue the objective to support Smart Cities implementation in a new context of science of cities.

Keywords:

- University curricula
- Smart City services
- Emerging technologies
- Innovation

- Science of cities

1 Introduction

We observe cities are receiving the biggest part of the worldwide population growth progressing more quickly than the national average (Assadian & Nejati, 2011). They are consequently the locus of major challenges to economize limited natural resources, to absorb the demand of jobs from the immigrants and to mitigate the negative effects due to the congestion of citizens in a space more and more reduced (Rodriguez & Bonilla, 2007). A rich literature echoes the reflection regarding the contribution of the cities to the global challenges through different concepts like Intelligent City, Wired City, Digital City or Smart City (Hollands, 2008; Komninos, 2006, Martin, 1978; Vespignani, 2009). More recently, many scholars suggest cities need to be understood not only as a sum of physical places but also of network systems and flows. They develop new ideas and applications for long-range future cities based on the Complexity science that they consider as the foundations of a new science of cities (Portugali, 2012; Samet, 2013; Townsend, 2013).

Emerging technologies like Big Data, Mobile, Social Media and Internet of Things enable groups to work together creating learning systems that behave as dynamic networks and whose number of nodes may vary up or down depending on the flow between them. The Complexity science introduces tools and framework that can be applied to analyze these networks and other structural aspects of the city (population density, dwelling surface and housing costs). This science provides theories to address urban issues and to establish predictive methods of interactions and flows to design next-generation cities. Emerging technologies are also an opportunity to innovate the services offered to the citizens. The cities that base their economy on the research, technology and the science are called Knowledge cities. In these latter, both private and public sectors create and capture knowledge, invest in supporting knowledge dissemination and discovery to create innovative products and services through the action of

clusters (Engel, 2015). However, Campbell (2012) highlights the academic circles have remained in the urban surface networks in spite of the national innovation governance (called Triple-helix model) that many cities have deployed to foster the interplay (Etzkowitz & Leydersdorff, 2000).

Therefore, our paper proposes to evaluate if the University academic programs are preparing the students to learn the technologies that the innovative services of the Knowledge-based economy requires. Our study determines the level of alignment between University and Smart City policies and identify possible gaps. We concentrate our analysis on the country of Spain which gathers excellent and internationally recognized universities along with state-of-the-art smart cities like Madrid, Malaga, Seville and Barcelona which hosts every year since 2011 the outstanding Smart City world congress. In our methodology, we list and classify the main innovative services of the Smart Cities and the emerging technologies which play an important role in the innovation of the urban services. Then we analyze the programs of different universities taking into consideration the large spectrum of science and technologies fields covered in Spain: Industrial Engineering, Civil Engineering, IT and Telecom Engineering, Physics and Mathematics, Technical Architecture, and Business administration for ICT companies. Finally, we conclude the level of alignment and draw different recommendations.

2 Defining the concept of smart cities

2.1 The science of cities

We live in a world where its future challenges like global warming, scarcity of the resources, or access to potable water have to be resolved in the cities. The growth of citizens whereas the resources available are more and more scarce (DESA, 2009) increases drastically the complexity of these issues and generates a lot of controversy debates (Madlener & Sunak, 2011; Assadian & Nejati, 2011). Cities as a sum of systems managed in silos have been studied hitherto through quantitative theories of built environment. Portugali et al. (2012) assert that Complexity science proposes to improve this analysis including also qualitative theories coming

from social field. Complexity science gives birth to a new science of cities and describes the behaviour of units system in interaction with its environment in order to maintain its future. This emerging science is an evolution of the civil system and its characteristics and demonstrates how entity interacts differently from what might be summing up the individual behaviour of each one. Samet (2013) shows that urban development is a process of guided self-transformation and the Complexity science can provide its internal rules integrating different parameters such as the urban classification (from township to megalopolis), the population range, the Gross National Income (GNI) per capita, the dwelling area per person or the cost of new housing per m2. This science makes consider an urban zone different than a 'self-organisation' like an ecosystem. The key parameter of the system growth is the investment capital that increases the complexity and the maturity of the city evolutionary structures. This new science of cities constitutes an important framework for developing planning standards and forecasts. It defines the macro laws for the evolution of the civil system, and prognostics for the long-term future in a horizon of 150 years from now. They are inputs for sustainable development studies and models of climate change to forecast the overall population density for human settlements, the world's land surface covered by urban zones, the remaining uninhabited land for wildlife or the level of forests and cultivated land (Samet, 2013).

2.2 The Connected city

The different technological (r)evolutions have connected the different systems of the cities through different networks (road, telecommunication, railway, network, energy, water supply) while the urbanization of the population was increasing and becoming one of the most important topics for social research. Neal (2013) justifies that the analysis of networks is an important tool for making sense of cities giving the opportunity to fill a gap in the social sciences known as the micro-macro issue and so, reevaluate question like how behaviours of individual people give birth to big urban phenomena. Whereas in the past, both graph theory and social network analysis treated networks as static structures, Newman (2010) applies the Complexity

science for the networks theory and shows how networks are the product of dynamical learning processes that add or remove edges that form it, modifying the pattern of nodes and the traffic between them. This complexity of interactions increases while civil or societal phase transitions arise at upper development stages like informational stage (Samet 2013). However, novel ICT capacities allow through the use of sensors the collect of real-time information concerning these networks like public participation of events in the city, traffic congestion, telecommunications and energy consumption. The simulation of urban models through the use of the technology gives birth to the concept of Smart Cities.

A lot of definitions of Smart Cities exist and for this study, we suggest to use a combination of the most applied definitions in the recent literature (Caragliu et al, 2011; Gershenson, 2013; Hollands, 2008; Komninos, 2006, Vespignani, 2009). They highlight four main objectives: improving quality of life of the citizens, increasing competitiveness and innovation for a new economy while keeping in mind the scarcity of natural resources. This new economy also called knowledge-based economy (Miles, 2005; Komninos et al., 2012) or in its more specialized grades, knowledge-based intensive economy (Gallouj et al., 2014) resides on the application of emerging technologies for the innovation of traditional historical services of the city. Neal (2013) argues that an abstraction of services into networks is a viable and holistic research strategy. He justifies it saying that a network-based analysis encompasses not only the pattern of relationships between people but also contextual factors of the city like culture or ethnic groups characteristics. He adds that the communities and the sense of solidarity instead of disappearing in cities, keep alive by virtue of their network structure i.e. the varied and numerous relationships that inhabitants maintain. But, such a statement puts maybe too much causal determination in the structure of the network. Greenfield (2013) responds "The city is here for use" and opposes himself to the top-down vision of a Smart City with centralized and network-based surveillance and control services. He shows furthermore the possible derives bringing forward different examples such as a large Siemens sensor system roll out that for the

unique collect of quantitative data in the network (misregarding qualitative ones) has driven to wrong decisions concerning security and safety aspects of the city. In his turn, Campbell (2012) adds it's not enough to be wired or high tech or high speed to take smart decisions illustrating it through different case studies in the world like Barcelona, Bilbao or Curitiba.

2.3 Knowledge cities

The development of strategies that facilitates investment in the producers of human capital i.e. University is an important factor to reach the Knowledge cities phase of the Smart City transformation (Bakici, 2012). Yigitcanlar (2008) identifies different fundamental key elements of these strategies like the technological aspect, the creativity and the development of urban clusters that give access to major infrastructure such as airports or research institutions (Engel, 2015). Leibovitz (2004) adds that the benefits of clustering for businesses include a larger talent pool, cost reductions, greater efficiency gains, and bigger opportunities to share. Campbell (2012) has conducted for over four years repeated visits and web-based surveys in 53 cities that unveil the reasons why the implementation of Knowledge cities may fail. He identifies amongst others that a small urban size impedes the creation of a critical mass of social capital and a lack of private interest the share of information. But he especially adds that a "cloud of trust" is mandatory for a city to learn, innovate and operate into Knowledge cities in the context of the knowledge-based economy (Ergazakis et al., 2006).

Universities have been long recognized as key components in the city for their role in training and education. The late 19th century witnessed an academic revolution in which research was added to teaching into the University mission. Actually, they have been effective vehicles for government-sponsored research initiatives that lead to major commercialization successes, such as the transistor, RFID, or internet. Fini et al. (2009) foresees the next-generation change in University and other educational institutions asserting they will be also effective catalysts and places of innovation community development. Etzkowitz & Leydesdorff

(2000) represent the national innovation system as the interaction of two historical forces: private companies and public administration but adding the role of the University as a third force and positioning it in a central role in the innovation (the so-called Triple-Helix model). However, Campbell (2012) analyzes the mechanisms of breakthroughs in innovation for urban environments and provides with a matrix crossing the impact levels with the different types of learning event: in-house or consultant firms seminars, university courses, City-to-City exchanges, reports or publications. He reaches the conclusion that the academic circles (along with consultant firms) come out at the bottom in the impact scale: "they have just remained in the surface networks already operating in cities". As a consequence, City leaders search outside for ideas and visit other cities to share information and learn from others. They do so because they know that their local university can hardly provide the useful knowledge and it is cheaper and less risky than pursuing untested ideas. In other words, the disruptive innovation generated by technology private companies or new innovative service requirements from citizens do not always push University to investigate and find answers and solutions.

This study aims at evaluating the relationship between the current Spanish university academic programs and the technologies that the innovative services of the future knowledge-based economy require in a context of Spanish Smart Cities. Moreover, it provides a framework of pre-filled templates based on the most recent documents published on Smart City and a 3-phases method that all together constitute a universal approach to analyze any situation occurring in other Smart Cities inside Spain or other European countries with its respective universities. Many papers have documented the main roles of the University (e.g. Rogers, 1995; Markman et al., 2005; Marzo-Navarro et al., 2009), but the literature is scanty concerning the matching with Smart City requirements.

3 Methodology

In this paper, we analyze the consistency between the current Spanish university curriculum and the new Smart City services and raise the question about the relevance of the teaching content received by the students. As said previously, the lack of preceding papers complicates the beginning of an answer and transforms the problem into a complex issue. Consequently, we decide to orientate our epistemological works on selecting and holistically analyzing the case of an urban organization which for its efforts and its topology make possible the acquisition of results and the extrapolation of our findings to other Smart Cities in the world (to some extent as we detail in the Academic conclusion section). For this paper, we shortlist the case of Barcelona based on the conditions stated before and confirmed by the outstanding ranking amongst the TOP 5 Smart Cities in the world in the recent IESE Cities in Motion index, 2015. Since we know that mobility of Barcelona graduated students towards other region of Europe/Spain is quite low (Ministerio de Educación Cultura y Deporte, 2012), the students of today will be the future workers of the knowledge-based services companies. Therefore, we can also restrict the scope of our empirical study to the universities of Barcelona.

Barcelona has four universities which are Universitat Politècnica de Catalunya (UPC), Universitat Pompeu Fabra (UPF), Universitat Ramon Lull (La Salle and IQS) and Universitat de Barcelona (UB). Since our study deals with technological innovation, we also confine our analysis to the programs directed to the technology learning and management which are split into six fields: Industrial Engineering, Civil Engineering, IT and Telecom Engineering, Physics and Mathematics, Technical Architecture and Business administration for ICT companies. Nevertheless, these universities form part of the Spanish educational system whose programs are directly managed by the central government like the rest of the regions. Therefore, it permits to extend our results to the rest of the Spanish territory and provides conclusions at a national level.

The absence of a model to transfer the Smart City requirements to the University leads us to conduct an interpretivist and deductive method where our primary sources of information

are the interviews carried out on Smart City experts. The sampling of interviewees is chosen equitably as per the Triple-Helix model to get a balanced opinion from possible contradictory points of view. Indeed, we interview 7 experts from private companies, 6 from public sector and 6 from University. In the private sector, we opt also for an equitable panel of professionals with different profiles but all assessing and developing knowledge and material on the subject for the Barcelona City Council. Two are international consulting firms investing largely on the Barcelona project for the Marketing interest that the city represents to their international clients. Two are local consulting firms with a close contact with Barcelona environmental context, and two are ICT companies providing the City Council with a technological assessment for the required solutions.

In the Public sector, we interview the utmost level of management in charge of the Smart City program: the Barcelona Smart City Director & Deputy CIO, the Director of Urbanism and three important leaders of Smart City Innovation centers: the Vice President of the International Association of Science Parks and Areas of Innovation (IASP), the Sub-Director of a non-profit research and innovation centre (i2CAT promotes mission-oriented R+D+i activities on advanced Internet architectures, applications and services) and the Director of Barcelona Fabric Laboratory (FabLab). Finally, on the University side, we select and meet managers who help us understand the different program curricula and validate our analysis.

We prepare two specific protocols of interview for the public and for the private area managers respectively based on the Smart Cities readiness guide (Smart Cities Council, 2015) and the McKinsey Global Institute Report (2013). The first one lists the state-of-art for the new services of a Smart City and provides best practices all over the world. The second one classifies twelve technology trends ranked according to their economical potential (i.e., the revenues forecasted for the private companies) and their gap in terms of the technological change. This list contains mobile internet, automation of knowledge work, internet of things, cloud technology, advanced robotics, autonomous and near-autonomous vehicles, next-generation

genomics, energy storage, 3D printing and advanced materials. A complete definition is given in appendix 1.

We analyze secondary sources to complete this methodology such as the 2014/2015 program curriculum of the different universities. To understand the Spanish context, in our discussion with local politicians, we carefully read the last OCDE report regarding the University education status in Catalonia and two published documents on innovation in Catalonia: the first one comparing the US model with the European one: "ICT Research and Innovation systems in the US and Europe" issued by I2Cat foundation and the second one suggesting the specified role that the Public sector has to take: "L'Administració pública com a tractor d'innovació" (in English, the Public Administration as an innovation driver).

4 Emerging technologies for innovative services

The interviews with Smart City managers aim at determining the services that the citizens claim to be improved in Barcelona and where actions are considered urgent. As an illustration, the maximum responsible for Barcelona urbanism states that the citizens want better energy and water services, the responsible for i2CAT innovation centre, better building environment and health and mobility services. Various initiatives respond to their needs like the mobile parking payment application, the 3D-printing studio network (called "Ateneos"), or the development of an alternative and greener heating system for the poorest zones of Barcelona. They also mention working on a framework that they call "city anatomy" aimed at shaping all the future services demanded by the citizens. The Smart City Director & CIO Deputy compares the benefits to draw an anatomy of a city to the labour done by the Doctors in medicine while effectuating the same exercise for the human body, are able to understand how the human system is running.

The progress consists in providing for the first time a holistic vision of the city services with its different structures: private or public built domains (like houses, public parks, libraries,

schools) where different transformations take place related to the different lifecycles of the water, the matter, the energy and in which information flows through communication networks and people on the move are geo-localized through their different mobility solutions (cars, bus, bike, trains, and metro). This vision is aligned with the recent works realized by Neal (2013) that demonstrates how networks, as observable patterns of relationships, influence cities and enable to understand urban needs and life issues. We note also the proximity with the Complexity science, the new science of cities (Samet, 2013) to understand and predict the cities characteristics and flows even if it was not mentioned during the interviews. During the anatomy exercise, the Barcelona city services are laid down to design a set of standard and scalable solutions that the service providers of the city are requested to invent and develop. Their requirements are based on an open-source software which make accessible for any single professional citizen create and build its proper and new services for the city. The choice to impose an open technology displaces the current one-way consumer role of the citizens into a co-creating role merging producer and consumer: the "prosumer" role as described by Seran & Izvercian (2014). In doing so, they give an equivalent chance between the independent hardware and software local engineers and the foreign private laboratories of international ICT companies to develop and commercialize the technology that equip the new services of the city.

Barcelona City Hall nourishes the ambition to share this framework with other cities across the world to take advantage of cost-effective and scalable solutions and enable the connections of services between cities. Therefore, we consider for our study the city anatomy as an optimal holistic description of the urban innovative services. Their classification includes five elements which are: living in a safe and secure house, improving transport solutions for people and goods, receiving care and health assistance, receiving education and services from the city, and better shopping experience with easier payment services.

5. Technologies for the built environment

We arrange several one-to-one meetings with C-level positions of consulting firms and ICT companies that are currently working on Smart City technological solutions and on their implementation. We prepare a protocol of interview with the objective to ask them which of the 12 technologies of the McKinsey Global Institute Report (2013) represent the main drivers for the five innovative services defined in the Barcelona project. Their opinions correspond to the real potential perceived in the field which may differ from the theoretical estimation carried out by a multinational management consulting firm. We also remark during the interviews that at least in Spain one technological project that embraces a complete transformation of the services of the city does not exist. We decide that the optimal way to analyze their opinions is to follow the classification of the five innovative services performed in the City anatomy document. For each of them, we present the key messages before resuming the complete answers in a matrix table.

5.1 The living services

Technology like sensors and meters are key assets to efficiently monitoring a large range of building functions like lighting, energy, water, heating ventilation and air conditioning (HVAC). The configuration of their embedded software allows reacting against dangers like fire, intrusion, elevator dysfunction and increasing security and safety services of the city. Besides, the CEO of an ICT start-up comments that Robotics drastically increases the capacity to collect information for the living services. He is currently working on Drones that, equipped with mini-sensors, provide 3D visualization of the Built environment (building, streets, avenues, etc.) and restitute city maps of heat, contamination, or pollinating rate in high resolution. This brand new company counts with several clients in the World with a presence also in USA. The original idea to create this company comes from a family issue. Indeed one of his daughters (along with other students of the same class) was suffering repetitive headaches in her school for an

unknown reason. His profession as an architect and his master in robotics technology (in UPC) led him to experiment the use of Drones to determine the contamination role in this pathology when traditional ground technologies were completely blind. He converts himself into the "prosumer" of an innovative living service for the city.

5.2 Transport solutions

Web portals improve the working conditions in cities providing online business services and reducing the need of transportation for workers and lengthy journeys between work and home. Barcelona City provides an on-line web application for future Entrepreneur streamlining the different paperwork with Public Taxes department (opening, tax return and closing). Social Media and Mobile services allow to know the city transport health and to offer alternative mobility solutions. One interviewee comments the results of the "Grand Nancy" project launched by an important French consulting firm and Nancy, a medium-size city in the north-east of France. They allow the workers to daily optimize their movement using the different mobility alternatives of the city and to report incidences in the public infrastructure during their transport. He adds that the complexity of such project resides in converging different existing solutions providing ad-hoc information of different resources of the city (bike-sharing service, tramway and bus geo-localization, and parking slots available) in order for the citizens to be able to rely on an end-to-end application to select and book mobility alternative solutions or to know a transport duration estimate. The application is quoted very positively by its users and new features are in progress to include the claim for assistance in case of lost objects and to also support entrepreneurs in the decision to localize their office and facilitate their employees in their daily commutation. Another interviewee also comments that 3D printing and drones have a positive impact on transport reducing the move of physical goods and materials that pollute the air.

5.3 Care and health assistance services

We observe during the interviews the recent success of the "*Vincles*" initiative, a Barcelona project awarded by the Bloomberg foundation in 2014 for the large contribution into the improvement of the health for the elderly. This project consists in providing a digital link through a private social media between the elder people alone at home and the rest of the city community (family, neighbourhoods, storekeepers) reducing the isolation risk and allowing to access medical advice via telephone or videoconference from home. Another interesting project is the Smart Citizen sponsored by the FabLab of Barcelona which seeks for deploying small meteorological platforms in every single Barcelona house (equipped with NO2, noise, humidity, temperature, particle and CO2 connected captors) capable of providing a full awareness of the city streets atmospheric conditions and empower the citizens to select the preferential transport mode.

5.4 Education and services of the city

We see for this service domain that the consultancy business is oriented to provide interactive online courses for the workers like Coursera or ITunes Academy and actually many universities already have their own MOOC solution. The progressive deployment of the fiber in the large and medium cities by ICT companies allows watching a movie or a theatre play in high resolution through on-demand Internet streaming media provider (Filmin or Netflix companies). Moreover, sensors and cameras technology solutions permit to collect information on the city security and safety parameters and to immediately react against risks like fire, terrorist attack, uncontrolled demonstrations, or robbery. The recent project in Rio de Janeiro shows how the implementation of a thousand cameras and digital sensors dramatically decreased the incidents of security yearly reported in the city.

5.5 Better Shopping experience with easier payment services

Most of the interviewees comment B2C Companies are investing hugely in consulting projects to better understand the consumer online shopping behaviour. These initiatives place

the digital "onlooker" in the middle of an systematic analysis of its actions in the social networks and websites so as to obtain detailed information of its interests and the potential articles he wishes to try and buy. The commercial brands while getting this feedback are able to determine buying behaviours and associate them to their customer value propositions. The connection to internet of the articles present in the physical stores through RFID technology informs which of them are really acquired by the potential on-line prospect. The convergence of information from off and online channels make possible, through Big Data solutions, to validate or refine the different customer buying patterns and to modify the marketing strategies in order to fit better with the desire of the clients.

This run of interviews provides a table of results that we submit to the private managers for validation. We receive their answers jointly with an important change. Indeed, they stress the transversal and essential role of Big Data/Analytics for all the five innovative services of the city. This statement was previously reflected in our table for the service related to better shopping experience. But they argue that Big Data while transforming large volumes of data into relevant information and leveraging the capacity limit of data collection to infinite, permits to operationally optimize all the business processes (transport, care, education, etc.) of the city, increasing their compliance by integrating business analytics, business rules and workflows. They confirm Mayer-Schonberger and Cukier's views that Big Data is a revolution event comparable to Gutenberg printing press and definitely part of the solution to resolve the critical problems of the cities (Mayer-Schonberger, 2013). They share also their concern regarding the dark side to Big Data: "Privacy has become more and more difficult to protect. The ability to capture personal data is often built deep into the tools we use every day, from Web sites to smartphone apps" Mayer-Schonberger and Cukier write (2013). And our interviewees give examples where Big Data solutions propose to Clients enhanced tariff due to predictive analysis of their future purchasing behaviour, with the final goal to alter their conduct. They add the

challenge resides that the Clients are really informed and consent on the use of their data. We integrate all these comments which lead us to the final results displayed in table 1.

Table 1

Relationship between new disruptive Technologies and Services of the Smart City.

	Mobile	3D-Printing	IoT Sensors	Big data	Drone (Robotics)	Renewable Energy
Living in a safe and secure house	Required		Required	Required	Required	Required
Improving transport solutions for people and goods	Required		Required	Required	Required	
Receiving care and health assistance	Required		Required	Required		
Receiving education and services from the city	Required		Required	Required		
Better shopping experience with easier payment services	Required		Required	Required		

6.0 Alignment of technologies with academic fields

The university system is divided in three different cycles which are the bachelor, the post-graduation and the continuous education for professionals. Our approach consists in analyzing the program curricula and checking the presence of modules related to the learning of the six emerging technologies defined previously. For each of the six academic fields of our study, we present the key findings before resuming the complete answers in a matrix table.

6.1 Industrial engineering

Since the first cycle, UPC introduces Python and other open-source programming languages and trains the students to create applications and web services. IQS introduces Visual Basic 6.0. 3D design and printing are part of IQS and UPC university programs but as an optional module in both cases. Analytics is only covered by an optional module in UPC where it is introduced as elements of statistical learning: data mining, inference, prediction and linear and non-linear models but not as the Big Data complete theme. We don't see either mobile or multi-dispositive applications technology covered by any module for the engineer graduation. In

the second cycle, Robotics and smart mobility (IoT) are introduced as an optional module when in the third cycle, user experience design and mobile solutions are covered.

6.2 Civil engineering

The only university in Barcelona graduating civil engineers is the UPC which however starts introducing emerging technologies modules only from the second university cycle. For postgraduate, UPC proposes two masters in sustainability. One is related to the Oceanography and the smart management of the marine resources. The other is part of an Erasmus program which deals with flood risks and its management in urban and rural zones. In the continuous education cycle, UPC offers 3 diverse programs in smart mobility, Smart City and sustainable urbanism where Mobile, IoT and Big data themes are taught. The classes leverage the leading position of Barcelona involving different actors of the Barcelona Smart City innovative ecosystem (City Hall, Regional government, Transport Metropolitan Company, and start-ups provider of smart solutions).

6.3 IT and Telecom engineering

UPF and La Salle train IT and Telecom students in diverse open-source and proprietary programming languages covering how to install and maintain servers, networks, web applications, database and create user-friendly front-end which correspond to the standard R/3 client-server architecture as first designed by the SAP software vendor in early 2000's. Multi-dispositive mobile applications, robotics, Internet of Things and sensors are also covered even if they are optional modules in UPF. In their Post-graduate cycle, La Salle covers a large spectrum of smart services and technologies associated to E-Health, Big Data, Energetic Efficiency, Sustainable Architecture, Mobility, Robotics, Domotics and Smart grid. Their alignment with the six fields of my study is unique; the strongest compared to the other Barcelona universities and position them as leader in the learning of Smart City technologies.

6.4 Building Construction Science and Technology degree

UPC and La Salle train students to become technical architects promoting the ethical responsibility by the use of renewable energy solutions as part of sustainable construction. La Salle's master for the urbanism management introduces new applied technologies to the urban planning and solid waste management. It covers the presentation of the Spanish Integrated Management System (SIG) for the selective collection and recovery of packaging waste for subsequent treatment, recycling and upgrading. More than 12,000 companies have joined the SIG in Spain. Its shareholders include 57 companies and groups comprising all of the sectors which participate in the management of packaging, from manufacturers and packagers to distributers, manufacturers of raw materials and recyclers. The UPC proposes in the continuous education cycle a master of 3D printing along with a Smart City one which includes basic elements of geo-referencing and Internet of Things solutions.

6.5 Business Administration for ICT

Students of UPC learn on mobile marketing technologies, digital survey method, the use of social media and web for ecommerce solutions. Big Data technology is introduced in La Salle to the graduating students. The UPF Master of science in IT Strategic Management emphasizes the role of this technology with concrete examples of applications for the Smart City and every year gives excellent opportunities to the students to apply for internships or full-position jobs in consulting firms or international ICT companies (Accenture, IBM, Urbiotica). The Master in Information Technology Management from La Salle gives a specific focus on the digital transformation occurring in the enterprise while its Master of Science in IT Management prepare to the tasks related to R&D and is a path to develop a career in the innovative technologies subject of our study.

The six emerging technologies covered in this study are not present in the Mathematics and Physics program curricula in the Barcelona universities. As a summary, we present the complete results in table 2.

Table 2

Relationship between technology and academic Fields.

	Mobile	3D-Printing	IoT / Sensors	Big Data	Robotics - Drone	Renewable energy
Industrial Engineering	Continuous Education	Bachelor	Post graduate		Post-graduate	
Civil Engineering	Continuous Education		Continuous Education	Continuous Education		Bachelor & Post graduate
IT and Telecom Engineering	Bachelor & Post-graduate	Post graduate	Bachelor & Post Graduate	Post graduate	Bachelor & Post graduate	Post graduate
Technical Architecture			Post-graduate			Bachelor & Post graduate
Business Administration	Bachelor		Post graduate	Bachelor& Post graduate		Post graduate
Physics & Mathematics	Not present	Not present	Not present	Not present	Not present	Not present

7 Discussion y Conclusion

The purpose of this study is to analyze the matching between the university program curricula and the innovative services so as to identify potential gaps in the current university model. Our empirical methodology permits to get respectively in tables 1 and 2 a relationship between new technologies and the services of the Smart City and between new technologies and academic fields. Therefore, we achieve the final goal merging the information of both tables and using technology as a pivot column. The relationship table between the innovative services of a Smart City and the academic fields is presented in table 3.

As an illustration, the merge reveals that "Living in a safe and secure houses services" needs knowledge that is taught in the Bachelors preparing Civil engineering, IT/Telecommunications and Technical architecture careers. Nevertheless, it appears insufficient because this service also needs the understanding of Big Data technological solutions that is missing in all these bachelors. The table shows also that post-graduate or continuous programs permit for graduated engineers to acquire knowledge that is missing in their Bachelor cycle and

so cover the whole technological spectrum required for Smart City innovative services. For instance, mobile technologies is learnt in bachelor for IT/Telecommunication engineers but not for industrial ones but the UPC provides continuous program education for them to cover this field. Besides, La Salle offers a Big Data master for all Engineers. For our discussion, we decide to focus only on the bachelor cycle because it gathers the huge majority of university students[1] and thus represents the most impactful academic program to permit the learning of Smart City new services.

Table 3.

Relationship between innovative services and academic Fields.

	Cycles	Industrial Engineer	Civil Engineer	IT - Telecom	Technical Architect	Physics & Maths.	Field missing to cover the whole service
Living in a safe & secure house	1st		Bachelor	Bachelor	Bachelor		Big Data
	2nd	Post graduate	Post graduate	Post graduate	Post graduate		None
	3rd	Continuous education	Continuous education	Continuous education			None
Improving transport for people & goods	1st	Bachelor		Bachelor			Big Data
	2nd	Post graduate	Post graduate	Post graduate	Post graduate		None
	3rd	Continuous education	Continuous education	Continuous education			None
Receiving care & health assistance	1st			Bachelor			Big Data
	2nd	Post graduate		Post graduate			None
	3rd	Continuous education	Continuous education	Continuous education			None
Receiving education & services from the city	1st			Bachelor			Big Data
	2nd	Post graduate		Post graduate	Post graduate		None
	3rd	Continuous education	Continuous education	Continuous education			None
Better shopping experience with easier payment	1st			Bachelor			Big Data
	2nd	Post		Post	Post		None

[1] Information from the Spanish Ministry of Education relative to Catalonia region. http://www.mecd.gob.es (last access: 22/07/15)

services		graduate		graduate	graduate	
	3rd	Continuous education	Continuous education	Continuous education		None

7.1 Breaking the silos of University programs

The first result is that University first cycle programs today don't prepare the undergraduates for the implementation of innovative Smart Cities services. The University structure based on technological departments such as Industrial, Information Technology, etc. is inappropriate for the services demanded by the citizens. The Smart City implementation needs to cross these silos and re-organize the University by business application and citizens' needs. This new approach faces an important resistance to change that Awbrey & Awbrey (2001) analyze concluding that two main barriers exist which are the wrong academic reward system too oriented to research and not to application and a trivializing of the integration built on that common sense suffices to achieve the necessary synthesis of the specialized in-silo knowledge. Moreover, our results also show that Business Administration graduation doesn’t incorporate the awareness of the six emerging technologies studied (only mobile and Big Data are covered). The gap between technology and business science should be also reduced in a context of the new digital company paradigm. Indeed, the digital Enterprise requires the Business managers to speak the technological language fluently and Feld & Stoddard (2004) add the Enterprise 2.0 oblige them to take business decisions on IT subject. Our results suggest the IT and business alignment is no longer the issue but it is rather converted into the full IT strategy integration at Company board level (Coertze & von Solms, 2014).

7.2 Mathematicians and physicists can contribute also to the Smart City debate

The Complexity science as the new science of cities (Samet, 2013) introduces a framework to analyze the Smart City structure (built surface, dwelling cost per m2, density by zone) and its population characteristics. It argues the features of a city is not deducible from the characteristics of an individual household or an establishment but measuring and analyzing the

dynamical flows and topological properties of the networks that innervate the different layers of the city (railway network, streets, power grid, telecommunication systems). Complexity science applied to networks (Newman, 2010) provides the conceptual view and the tools to establish predictive methods of interactions and flows and resolve urban issues. Mathematicians and Physicists in their graduate careers learn these theories that they could apply placing the urban problematic in the heart of their expertise and domain of competence. They have the opportunity to contribute also in the rise of the Smart Cities.

7.3 Big Data technology is missing in the Engineer careers

Our analysis of all the universities curricula show Big Data technology is not learnt in any engineer graduation careers but is present in the second and third cycle of some universities (like La Salle for instance). As one consultant explained us, the exponential number of people and things connected to the city make Big Data technology essential in the implementation of the future services of the city. As we have said before, Barcelona through the City anatomy model considers the urban zone as a sum of networks interrelated which raises diverse questions of management and resilience for the city. Big Data allows to monitor the current flows and to make proven predictions such as what would happen to the basic services of the citizens (water, electricity, wastewater, etc.) if for three days the number of inhabitants of Barcelona increase by 100.000 due to an international congress or an international sport event. Or what would be the impact for the services of the city (Telecommunication, energy services, waste services, etc.), of the arrival of 50.000 tourists for a large Musical concert. Engineers have developed large "hard" skills to work on Big data algorithms and develop models of answer. It is an opportunity for them to form part of the strategy change argued by Huberty (2015) to trigger the cities jumping to the third industrial revolution so much announced but still not started.

7.4 IT/Telecommunication play a central role for the Smart City services

Our results show that IT/Telecommunication engineers are central in the realization of the innovative Smart City services compared to the rest of careers (Industrial, Civil, architecture, etc.). This role consists in the creation of online applications to improve services such as transport or making cheaper and faster professional services like care and health assistance for the citizens. In a period when government is looking for savings to reduce debt and public deficit, this IT lever can't be neglected. Software engineers should acknowledge the social mission of their future profession. When we met one of the City Hall managers, he pointed out the paradox that the successful social media application called "*Vincles"* and already cited (an 100% IT project for improving the life of elder people in Barcelona), was not an idea of Barcelona City Hall IT department but of the Health one ("Bienestar") although this latter does not own any IT professionals in its team. This is a clear evidence of the existing chasm.

Some solutions are in progress. Kurland et al. (2010) present an initiative launched by the California State University Northridge (USA) which trains all their students of the seven specialized colleges in business management, science, and technology on sustainability subject during a 14-week course. Their objective is to ensure that each single undergraduate acquires an interest on the global sustainability issues and how his specialization matters for the everyday living. Kurland et al. (2010) comment the success of this initiative accredited by positive students' surveys but enlighten also that this interdisciplinary course faces challenges and list amongst others a lack of leadership on the program content or an increasing entropy of administrative tasks. They add that this initiative is not isolated since in 2010, 19 undergraduate and 60 graduate business similar programs existed in USA. Sustainability awareness joins a previous and older discussion related to the general Ethic mission of the engineer. Passino (2009) declares concerning this subject that unfortunately little has been done so far in engineering universities to support humanitarian efforts. He points the limited results of various pedagogical strategies introducing codes of ethics or moral frameworks that after his opinion

have rarely encouraged engineers to serve later as volunteers for the service of the community or the city.

7.5 We need scientists to become engineers to invent technologies that don't exist today

Our results show that Physics and Mathematics program curricula are not influenced by the emerging Technologies. Nevertheless, the scientific literature shows us that important technological inventions were discovered also by scientists in the past. Their research leads them to become engineers imagining the tools able to validate the scientific model that they build theoretically. Haeusler (2012) recall that Alan Turing was first a recognized mathematician graduated at King's College in Cambridge in 1934 dedicating his research to the mathematical view of Intelligence and Life. But his name is mainly associated to his works on the development of the computer science, and the technological invention of a universal machine able to compute the algorithms developed by other machines, which is considered as the model of the first computer Turing (2009).

Biomedicine has recently offered two examples that show this field is progressing leveraging the nexus of technology and science. Trepat et al. (2009), Doctor of Physics, worked on the physic laws that exist at nanometric scale with the objective to prevent the metastasis generation and calculated a theory of forces along with the construction of a "technological machine" to measure and validate it. Trepat received in 2014 the Sabadell Bank prize for the investigation. The Centre for Genomic Regulation (CRG) (an international biomedical research institute of Barcelona) provides our second example. Indeed, Gómez et al. (2010) investigate on the DNA patrimony and on the bacteria "Mycoplasma pneumoniae", one of the main causes of pneumonia for the children. Using different physical equations of fluids and a 3D mathematic model, they identify and localize the different regions of the chromosome and finally understand the functioning of transcription and translation processes in the cell. Their aim now

is to invent the technological machine, the engineer therefore being who validates their physical scientific model.

7.6 3D printing innovates the manufacturing services

Starting in the early 1990's, the outsourcing wave of our capacity of production from Occident to Asia regions has progressively vanished our efforts achieved after two industrial revolutions to master techniques to build and manufacture any functional objects or machines. It is also the cause of massive job loss in Europe and USA. Moreover, Kakabadse & Kakabadse (2005) comment that both European and US companies consider outsourcing as critical to their organizational strategy and overall report higher levels of satisfaction than expected.

Our results show 3D printing is not systematically included in the academic engineering programs. Only the Industrial engineering program has this module as an option for their students. We observe universities have not yet identified the opportunity residing in the 3D printing to revert the past outsourcing trend and repatriate the jobs lost in the manufacturing sector modifying the equilibrium of forces in this market. Indeed, the first contribution of this technology lies in moving the battle field from massive to small market groups and to manufacture in a cost-effective way compared to the low-salary productive countries (Berman, 2012). The second contribution is to modify the bargaining power between competitors. Mohajeri et al., (2014) say 3D printing is a lever to produce customized products and to match more successfully to the rapidly changing needs of the customers, while giving them a more interesting role from passive to being fully active agents in the manufacturing of the products ("prosumer" role again). Many cities in Europe have implemented Fabric Laboratories (Fablab) where residents have the capacities to prototype their invention and manufacture products. University curricula should be re-designed to take large advantage of this new available infrastructure. Today in Barcelona, the IAAC school of architecture is for instance partnering with the local FabLab.

7.7 Academic conclusions

The objective of this study was to analyze the matching between the university curricula and the innovative services of the Smart City that aim at improving the quality of life of the citizens. Due to the complexity of the question involving important and vast themes like Smart City, University, Innovation and the role of technology, our decision was to limit our study to the case of Barcelona. The leading position of the Catalan capital and the international ranking of its University motivated this choice for the possible extrapolation of the collected results. We followed an interpretivist and deductive method based on a set of interviews with Public, Private and University managers, being in full compliance with the innovative model largely known as Triple-Helix. These interviews drove us to also consider a list of secondary sources like the City anatomy or the McKinsey Global Institute Report (2013) which contributed to the elaboration of the following results.

This study demonstrates the innovative services that the City Hall of Barcelona is working on for the benefit of its citizens are supported by six emerging technology trends which are: Mobile, 3D-printing, Internet of Things, Robotics, Renewable Energy and Big Data. Except the last one, we have found all of them present in the curricula of the four universities graduating engineers in Barcelona. This leads us to conclude that these curricula should be revisited to insert also the knowledge of Big Data technology. Secondly, our findings demonstrate the organization of the University today in technological silos is a strong barrier to provide a complete set of competences to the engineers for implementing the future services of the Smart Cities. The Industrial Engineering career was created for the second Industrial revolution; we suggest developing Smart Engineering careers for this next revolution.

Thirdly, Physics and Mathematics graduating curricula seem to be living isolated today from the transformation occurring close to them. Nevertheless, they could play an important role by applying the Complexity science to networks and so redesigning the services that address the current challenges of the cities. Moreover, we recommend to introduce in their

curriculum a technological and business application perspective of their science. Recent examples in biomedicine present outstanding results that make sense to be reproduced. Fourthly, our results highlight the Business Administration careers incorporate only the learning of Mobile and Big Data technologies and should insert the 4 remaining technologies of our study. The students will speak technology fluently and understand the relevance of IT for the generation of new business opportunities building the so-called Digital Enterprise or Enterprise 2.0.

Fifthly, IT and Telecom graduating careers play a central role in providing these new social services which could be however considered as far from their technological concerns. IT/Telecom engineers' curricula should be redesigned to include social, ethics, and sustainable responsibility and permit the awareness of the social purpose of their field. This initiative would surely promote the emergence of new ideas and applications for the future of the cities. Sixthly and finally, University has not yet acknowledged the historical opportunity that 3D printing offers to build the objects of the Smart City. The potential benefits are however to increase the customization of the services provided, reduce the manufacturing costs and promote the re-localization in Europe of the jobs lost during the last outsourcing era.

Our investigation proposes a methodology composed of pre-filled templates and describes a 3-phases approach that could be reused for analyzing the situation of other Smart Cities in Spain or even further considering European urban agglomerations. Anyway, the characteristics of Barcelona's situation, a sea-side metropolis of more than 1.5 million inhabitants with a large proportion of built infrastructure could limit the comparison of the collected results with other European cities. The choice of universities has been restricted to the Barcelona-based ones. It could be interesting to check the conformance of our conclusions with the rest of the large universities close to Barcelona city and that could influence also the Triple-Helix innovative ecosystem of Barcelona like for instance the "Universitat Autonoma de Barcelona" or the "Universitat Rovira i Virgili" where the CIO of Barcelona City Hall is currently

teaching. As a final word, we stress the importance of our suggestions being based on the aim of preparing University to address the revolution that occurs in the City, our results and respective conclusions are relevant to the extent that University pursues this objective and not a different one.

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