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What makes a city smart? A roadmap to smart city development.

More and more, words like 'connectivity', 'sustainability', and 'e-governance' are heard in the media. These words can all be encompassed by the 'smart city' concept. Smart city initiatives such as 'Smart City 2.0' are sprouting around the globe. 'Smart City 2.0' is an initiative of the Canadian government, who wants to transform its capital, Ottawa, into a smart capital. In order to this, they opened a competition where the best smart city project for Ottawa will be rewarded by 50 million Canadian dollars. This project aims solve Ottawa's problems through smart development. The main challenge in this project is that Ottawa is a very rural city, which means that the connectivity between different parts of the city is limited (CBC News, 2017). IT2000 Singapore is another smart city initiative. This initiative consists of a partnership between Singapore's government and the National University of Singapore (NUS). In this partnership, NUS pledges to provide formations in data science to 2000 public officers every year. Singapore's strategy is to update its labour force to meet the needs of smart cities, which is mainly the capacity to process information rapidly and in huge quantities (Channel News Asia, 2017). Finally, another example of a smart city is Barcelona, this city is considered as one of the most advanced European cities in terms of technology helping citizens, they have an enormous number of sensors gathering information on bins, parking spaces, traffic lights, etc, alongside free Wi-Fi in the city. Having all this, the municipality would still like to rethink and improve its smart city strategy (Financial Times, 2017). The fact that three major cities on three different continents are working on smart cities shows how important this concept is to the future of urban development. However, a proper definition of the concept lacks.

This paper aims to present a road map to smart city development: what are the most important sectors to develop in order to become smarter? And how important is each of these sectors? These questions have to be answered taking into account the lack of an official definition of smart city.

The first part of the paper presents a literature review that determines which aspects of smart cities, and cities in general, are the most important. This part will also generate the hypotheses tested in this paper. The second part of this part describes the data and explains the methodology used in the research. The third part will present the results as well as the interpretation. Finally, some limitations to this paper will listed.

LITERATURE REVIEW

What are smart cities? and why are they relevant today? The concept of smart cities is becoming increasingly popular and governments now take advice from researchers to make their cities smarter. More and more academic literature is being published about this subject, however a fixed definition of smart cities has yet to be agreed on by the scientific community. Moreover, the term 'smart' is often interchanged with other terms such as 'intelligent', 'ubiquitous', and 'digital'. It is obvious that the concept of smart city is not well understood and therefore needs to be clarified.

Firstly, it is important to understand what the term represents and why it is relevant. In 2014, 53% of the global population lived in urban areas, this value amounted to 48% just 10 years ago (World Bank, 2014). This highlights an upward trend of urban population growth and therefore an increasing pressure on city performances. Cities are more than ever the centre of human actions and their externalities; therefore, they need to perform better and better as their populations keep increasing. Cities suffer from pollution, congestion, ineffective infrastructure, inequalities, etc. The concept of smart city has come to represent forward-looking development to solve these problems. This explains the confusion between 'smart', 'intelligent', 'digital', etc. Governments aim to develop their cities to become smart cities as this concept represent cities that are responding to the challenges emerging from their individual situation in the most effective way. The concept of smart city is therefore associated with urban development.

As stated earlier, there is no official definition of smart cities. The following part will give an idea of a general and large definition of this concept, and will determine the most important dimensions of smart city development.

A. Technology

Originally, the definition of a smart city is a city that integrates Information and Communication Technologies (ICTs) in modern infrastructure (Vito Albino, Umberto Berardi and Rosa Maria Dangelico, 2015). The concept has evolved, however, the use of technology is still a central aspect of smart cities, as shown by the numerous definitions emphasizing the use of technologies:

- "Smart cities are all about networks of sensors, smart devices, real-time data, and ICT integration in every aspect of human life." (Cretu, 2012)
- "Being a smart city means using all available technology and resources in an intelligent and coordinated manner to develop urban centres that are at once integrated, habitable, and sustainable." (Barrionuevo et al., 2012)
- "The application of information and communications technology (ICT) with their effects on human capital/education, social and relational capital, and environmental issues is often indicated by the notion of smart city". (Lombardi et al., 2012)
- "The use of Smart Computing technologies to make the critical infrastructure components and services of a city—which include city administration, education, healthcare, public safety, real estate, transportation, and utilities—more intelligent, interconnected, and efficient." (Washburn et al., 2010)
- "Smart Cities initiatives try to improve urban performance by using data, information and information technologies (IT) to provide more efficient services to citizens, to monitor and optimize existing infrastructure, to increase collaboration among different economic actors, and to encourage innovative business models in both the private and public sectors." (Marsal-Llacuna et al., 2014)

These definitions are a few amongst many to use technology as a way to achieve some urban development goals. It is true that with today's technology and the internet of things, new opportunities for development come to light. Smart object (or connected objects), offer data collection which can lead to an optimal allocation of resources according to real time needs. This emphasis on the technological component in 'smart cities' is well justified in IBM publications on the topic.

Cities can be seen as a cluster of systems (Dirks and Keeling, 2009). In their IBM report, the two researchers look at cities from a systemic angle; a city is composed of different systems such as the business system, the transport system, the energy system, etc. Each system gathers data that can be shared. These systems are usually managed by different entities; however, they do interfere between themselves in a way that Dirks and Keeling call a "system of systems". Each of these 'subsystems' is

still imperfect, for example the water system may have too much water pressure at certain times, leading to water leakages. These problems can be detected faster with technology (sensors), and they must be improved in the future. The point made in this report is that thanks to technological progress we are coming closer and closer to a system of systems which can optimally regulate all the systems. A city with such a system of systems is a smart city.

A year later, Hamilton et al. (2010) published another IBM paper which connects with Dirks and Keeling's work. In this paper, the authors define the foundational concepts of a smart city, which are: an instrumented, interconnected and intelligent city. These three terms define the meaning of 'smart' in 'smart city'. 'Instrumented' means that the city is equipped with tools collecting "near-real-time real-world data from both physical and virtual sensors". The term 'interconnected' means that the near-real-time real-world data is shared between the systems. Finally, 'intelligent' means that the data is used in a way that optimises production of city services and utilities. These three terms depict well the 'system of systems' that a smart city should have. Moreover, it is important to notice the use of technology, more precisely ICTs, in the urban development process.

Technology is a central concept of smart cities. Cities must keep updating their technology if they want to be a competitive smart city, they must contribute to technological progress. If there is a technological breakthrough in a city, they should exploit this technology in order to be on the forefront of technological progress. This is why some cities are subsidizing research and development. For example, the Eindhoven municipality is financing a part of the Milestone Project. The Technical University of Eindhoven is building a 3D-printed residence, it is the first time that people will be living in 3D-printed houses. 3D printing for housing is a technological revolution and Eindhoven will have a head start if this project succeeds. Eindhoven is also the 8th smartest midsize city in Europe (Meijers, 2007), showing that a municipal government supporting research and development is important for the development of the city.

Supporting innovation is very important, this leads to the first hypothesis: *cities that have an innovation-friendly environment are smarter.*

B. Social

It is clear that technology plays a central role in the development of smart cities. However, it is unclear as to what the ultimate goal of developing a smart city is. Illustrating this, certain definitions focus on education, others on health and others on the development of the private sector. A common theme still arises: the importance of human welfare and of the quality of life.

It can be argued that cities are first and foremost a place to live for citizens and then a place of business. A city is a place where different utilities and amenities exist because of the human presence and the population's needs; every aspect of a city should ultimately serve a social purpose (Mumford, 1937). The key word here is 'should'. Indeed, as Mumford points out, in the last century we have been focused on the development of other aspects of cities forgetting about the development of the "social nucleus" of the city. This type of economic-growth-focused development is not sustainable as it will eventually lead to war over scarce resources and natural disasters linked to global warming (Rifkin in 'the Third Industrial Revolution', Vice Documentary) and neglects the social aspect of cities. Our growth-focused economy is not a sustainable model, it will lead to competition between countries eventually hindering development. This is why this paper will mostly use Mumford's social definition of a city. Developing a city means that it thrives to increase the quality of life for its citizens and develop the social nucleus.

Hollands (2008) makes a similar point. In his paper, 'will the real smart city please stand up?', Hollands observes that the majority of academic writers put the human and social dimension at the centre of their research. The author states that "progressive smart cities must seriously start with people and the human capital side of the equation". Trusting that technology will enable progress is too hopeful, this technology must be socially oriented, which means that the technology must be implemented with a social goal in mind. Holland points out that many smart cities focus on the development of new technologies while hiding social polarization. Indeed, government investments that try to create a business-friendly environment to boost technological progress, are a diversion of public funds without holding any guarantee. Indeed, these investments ultimately go towards economic/technologic development instead of social development. While these investments might achieve their intended aim, which is to attract ICT businesses, these businesses can easily change location once they find a more profitable outside option. Eventually, these types of investments increase the social divide. Hollands also notes that real smart cities use technology to put the democratic debate about social issues forward; technology can be used to include everyone in the debate and eventually in the decision-making. This is called 'smart governance' and is used by many papers as an indicator of smart cities. Therefore, for a city to be smart, it needs to take into account its people. Everyone should be part of the development as it is easy to forget about a part of the population while labelling a city as being smart.

Academics agreeing with this point of view on cities usually focus more on smart communities with a strong emphasis on social capital, education and social leaning in the development of cities (Eger, 2003). It is true that technology can greatly help in the development of smart cities, however technology by itself does not suffice. The technology needs to be simple enough so that the

community can use it easily. And the technology needs to be usable. For example, in 2017, the Economist pointed out that in many African countries, more people had a cell phone that the number of people with access to electricity. This means that although the communities have the technology (the cell phones), they cannot use it to its full potential. Therefore, for a smart community to exist it needs to have access to the technology and be able to use it. This idea is even enforced by research showing that increasing technological development in a city will emphasize disparities (Graham, 2002). Indeed, usually the technology is exploitable by a certain fraction of the population, usually the middle-class an above. Moreover, such technological development attracts students and young professionals; people who will be or are already educated and who are capable of exploiting that technology. As a result, the lower class stays the lower class and does not see the benefits of the technology.

To summarize, understanding clearly the 'smart city' concept requires one to look at 'smart' and 'city' separately. Cities are a place where people live, as a result the ultimate goal of urban development should be to increase the quality of life. The word 'smart' refers to the fact that technology enables such urban development and that the urban development is achieved through technology, ICTs more precisely. The social aspect of a city is a core concept of smart cities. Cities should aim to develop their social capital.

This leads to the second hypothesis: *a city that is more socially liveable is likely to be smarter.*

C. Sustainability

A definition that recognizes the importance of technology as a way to develop quality of life is one coined by Caragliu, Del Bo and Nijkamp in 2011. They define smart city as a city that invests "in human and social capital and traditional (transport) and modern (ICT) communication infrastructure fuelling sustainable economic growth and a high quality of life, with a wise management of natural resources, through participatory governance." These researchers came up with this definition after following a project by the Centre of Regional Sciences at the University of Vienna which identifies six axes on which cities must focus to become smart: smart economy, smart mobility, smart environment, smart people, smart living, and smart governance. This framework has also been used by several researchers to make smart city rankings. This definition is one that is recognized, and it is important that it highlights two main goals: high quality of life and a sustainable economic growth.

The term sustainable development was officially defined in 1987 during the Brundtland Commission: "Sustainable development is development that meets the needs of the present without

compromising the ability of future generations to meet their own needs"(Brundtland, 1987). This concept is becoming more and more important as the issues related to global warming, resource scarcity and pollution are becoming more apparent but also because people are becoming aware of these issues. Corporations are already reacting to this by focusing more on their Corporate Social Responsibilities. Cities should do the same.

Indeed, our society depends on the environment. For decades, we have failed to understand that blindly focusing on our economy is not sustainable as the economy depends on the environment. The economy depends on society, which depends on the environment (Giddings, Hopwood and O'Brien, 2002). It is recognized that human wellbeing should be the main aim of economic development, Giddings et al. point out that humanities depends on the environment. Furthermore, the authors argue in favour of an integrated approach to sustainable development. Such an approach would enable to overlook the trade-off between poverty and depletion of the environment. An integrated approach to sustainable development highlights the fact that demand can be met sustainably. Making sustainable development a seducing idea.

However, many argue that sustainable development is not achievable, this is due to the fact that the term sustainability is widely misunderstood. Sustainable development should be approached as a process instead of a project with finite goals (Hjorth and Bagheri, 2006). Therefore, sustainable development is not a goal in itself, it is a transformation of production and consumption from an unsustainable process to a sustainable one. This transformation must be undertaken at every level of our system, this is why many papers refer to a systemic approach or a holistic approach. Sustainability is a process that must be undertaken in order for future generations to develop. Therefore, sustainable development is achievable as it is a step by step progress. Moreover, it is a necessity to start this process.

Furthermore, Hjorth and Bagheri (2006) highlight that development today is the result of progress due to specialization in distinct domains, but that advancing in sustainable development requires a synthetic look "through some kind of multilevel and multi-dimensional graph of interconnections". This is very interesting as the 2010 IBM report mentioning a system of systems overlooking the city's different domains of activity. A smart city with such a system of systems would enable the synthetic look needed to achieve sustainability. This is supported by research showing that smart city initiatives can enable a more sustainable development. Illustrating this, Barcelona is planning on saving millions in energy costs through their smart city initiative, for example they will implement a system dimming street light when they are not useful (when there is no one around), according to CNBC.

Sustainability is one of humanities goals, it even has been registered as one of the UN's Millenium Goals. Moreover, smart cities are a great way to achieve sustainability. Real smart cities have a duty to achieve sustainability. This leads to the third hypothesis: *Cities that are environment-friendly are smarter.*

DATA AND METHODOLOGY

The data used in this paper is taken from the Euromonitor Passport database. This database offers numerous city indicators over a period of eight year (2005 – 2013). Using these indicators, a ranking of cities in terms of smartness has been made using the methodology proposed by the Centre for Globalization and Strategy. The ranking includes 126 global cities which are divided in four groups, using the Penas distance method, according to their degree of smartness: *smart1, smart2, smart3* and *smart4* (Wall and Stavropoulos, 2016).

Hypothesis 1: To measure the extent to which an environment is innovation-friendly, a number of different variables can be used to come up with an innovation-friendly index. However, this paper identifies two important variables that make up such an environment: a variable showing the time needed to start (in months) a business, and a variable giving a measure of human capital; two essential factors to a high innovation rate.

Human capital is an important factor of innovation. When innovation is an important factor of growth, the latter can fluctuate greatly according to the level of human capital (Benhabib and Spiegel, 1994). Human capital represents the production potential of a workforce. A high value in human capital is an indicator that a population is qualified and has experience, making it easier to produce new ideas and carrying them into research and development. Human capital is one of two variables used in this paper to assess the innovation propensity of a city. A common way of measuring it is by calculating the return on investment on education and formations.

The other variable that is used is the time required to start a business. Time required to start a business is measured in months, it is generally a good way to study the time needed for new ideas to come on the market. Moreover, it shows how fast it can be for a new product or service to enter the market. Therefore, a short time to start a business, together with a high human capital, should generate ideas at a significant rhythm, as well as commercializing them.

Hypothesis 2: Assessing the social performance of a city can be done by looking at the equality and cohesion within the city population. In this paper, social equality is measured by the Gini Index. The Gini Index is widely used as a tool to measure disparities in populations. A score of 1 shows pure inequality and a score of 0 shows perfect equality in a population. It is interesting to look at the Gini Index because it shows the magnitude of disparities. Inequalities in wealth are often a factor of tension and conflict between different classes in a society. A low score on the Gini Index is therefore a good indicator for a peaceful society/population.

Social cohesion is also used in this paper as an indicator to show the level of integration individuals have in a population. The social cohesion indicator is made of several sub-indicators, such as the sense of belonging, social justice and equity, and participation in citizen duties as shown by the social cohesion index by the Scanlon Foundation. The happiness level and quality of life in a city are largely defined by the degree of social cohesion. This is well illustrated in one of Durkheim research. Indeed, Durkheim explains suicide as a reaction to the absence of social ties. Individuals who are not well integrated in their society tend to commit suicide as they have no one to rely on (Durkheim, 1897). A high score in social cohesion is a good indicator to study the happiness level of a population.

Hypothesis 3: to study the extent to which a city is sustainable, this paper looks at the environmental index. One of the reference environment indexes is Yale's Environmental Performance Index. This index studies how cities perform on an environmental level. To do their analysis they collect data on different facets of the environment that are affected by a city's activities. These facets include, water quality, CO2 emissions, sanitation, nitrogen management, etc. A high score on this index means that the city cares about sustainability and that significant actions have been taken to increase the sustainability of the city's development. It shows concern for one of the toughest global challenges.

The hypotheses are tested with an ordered probit model, which can be illustrated by the following equation:

$$SmartRank = \Phi\,(\beta_0 + \beta_1 * \text{Time required to start a business} + \beta_2 * \text{Human Capital} + \beta_3 * \text{Social Cohesion} + \beta_4 * \text{Gini Index} + \beta_5 * \text{Environmental Index}) + \varepsilon$$

With Φ indicating a standard normal distribution.

Moreover, the following table shows a summary of the characteristics of each variable that is used the in the ordered probit and probit models.

Variable	Obs	Mean	Std. Dev.	Min	Max
Timerequiredtostartabusiness	1130	24.48	26.48	0.5	156
humancapital	1125	2525.91	3458.33	106.64	28678.46
socialcohesion	1134	3442.83	5978.35	68.47	44785.17
GiniIndex	1134	40.69	8.05	23.5	69.3
environmentalindex	487	67073	13.92	0	95.51
rankgroup	1134	2.83	0.94	1	4

Table 1. Summary of the variables used in the study.

Time required to start a business is measured in terms of months. It goes from the 0.5 month, for the fastest time to start a business, to 156 (or 13 years) for the longest time. The average time to start a business is a little bit more than two years. Moreover, there 1130 observations out of 1134 possible meaning that there is data on most cities

The level of human capital has also been observed for most cities and years with 1125 observations. Since human capital is measured in terms of spending on education or formation, or as a return on these investments, the higher the human capital value, the higher its level. The maximum value in this dataset is 28678.46 and the lowest is 106.64, with a mean of 2525.91.

The indicator for social cohesion is observed for every city and every year. This indicator is a score based on a series of other indicators. The higher the score, the more a society is cohesive, building trust, creating a sense of belonging and fighting exclusion. The value of the social cohesion indicator goes from 68.47 to 44785.17 with a mean of 5878.35.

The Gini Index is also observed for every city and every year, with 1134 observations. The scale of the Gini Index goes from 0 to 100. Complete equality being represented by the 0 and pure inequality by the 100. Out of the all the cities that are studied, the city with the best score shows a value of 23.5 on the index. The one with the worst score shows a 69.3 on the index. The average score for the studies cities is 40.69.

The environmental index is also measured on a scale of 100. However, the best score is 100 and the worst score is 0. The city scoring the best on the environmental index shows a score of 95.51, and the worst one shows a score of 0. The observations for the environmental index are incomplete, indeed, there are only 487 observations. The index was not observed for some of the years and some of the cities.

Finally, the rank group is the dependent variable, for every year, each city is classified in one of four categories, according to their level of smartness. 1 being the smartest and 4 the least smart.

RESULTS

BASELINE MODEL: OPROBIT

VARIABLES	rankgroup
Timerequiredtostartabusiness	0.0118***
	-0.00255
humancapital	-4.92E-06
	-5.07E-05
socialcohesion	-0.000255***
	-3.42E-05
GiniIndex	0.0507***
	-0.00799
environmentalindex	-0.0250***
	-0.00417
/cut1	-2.555***
	-0.461
/cut2	-0.483
	-0.427
/cut3	0.819*
	-0.429
Observations	483

Table 2. Baseline model of study: ordered probit of the five indicators on smartness of cities.

Initially, the overall effect of each of the five chosen indicators on the smartness of cities is studied. As stated before, the cities are classified into four rank groups according to their level of smartness: category 1 being the smartest, and 4 the lowest; the higher the rank group, the less smart a city is. Table 2 shows the result of an ordered probit of the indicators on these smartness categories.

Firstly, it is shown that time required to start a business is positively correlated with the rank group. This correlation is significant at 95%. Moreover, the standard error is relatively small. This means that the smarter a city is, the less time it should take to start a business. In other words, a city in which it takes one year to start a business should be smarter than a city in which it takes five years.

Furthermore, the human capital index has a negative impact on the rank group of a city. However, it is highly insignificant. In fact, the p-value is equal to 0.923. This means that human capital is not important in determining the smartness of a city. Having a higher level of human capital will not necessarily enable a city to become smarter.

The social cohesion indicator has a significant impact on smartness, this impact is positive. Indeed, social cohesion is negatively correlated to the rank group, therefore a higher level of social cohesion leads to a lower rank group (which shows more smartness). The standard deviation of this relationship is also relatively small.

Moreover, the Gini Index shows a positive impact on the rank group. The higher the Gini index is, the higher the rank group of a city should be. However, a high value on the Gini Index show more inequality. As a result, table 2 reads as follows: more inequalities within a city population leads to less city smartness.

Finally, the environmental shows a highly significant negative impact on the rank group. This means that cities that take care of their environment and that support and develop sustainable processes are smarter. In this case, the standard error is also relatively small, making this observation reliable.

So far, the first hypothesis is rejected: it was expected that the time to start a business was positively correlated with the smartness category, and it is. However, human capital, a very important factor in innovation, is insignificant. At first glance, a city does not necessarily need to be an innovation-friendly environment to be smart. However, the second and third hypotheses cannot be rejected by the base model. Indeed, it seems like cities that promote social equality and cohesion are smarter, the same goes for cities that promote sustainability.

This base model is useful to understand general trends. However, every city is on a different level of smart development and it may be that different smartness levels manifest different development needs or achievements. This is why, probit models were exercised on different rank groups separately, in order to identify the different characteristics of the smart development stages. The results of these regressions are summarized in table 3.

Table 3 shows that the most significant factors for category one smart cities are the environmental index and the Gini index: both of these factors are significant at 99%. The environmental index variable is positively correlated with the smart 1 variable. This means that the higher the score of a city on the environmental index the more it is likely to be very smart. Furthermore, the Gini Index is negatively correlated with the probability of being called very smart. However, a high score on the Gini Index is an indicator of high inequalities within a population. In other words, very smart cities can be associated with relatively low inequalities, compared to other cities. The three other indicators are insignificant for the smartest cities.

VARIABLES	smart1	smart2	smart3	smart4
Timerequiredtostartabusiness	-0.0252	-0.0270***	0.00453*	0.0137**
	-0.0159	-0.00513	-0.00251	-0.00544
humancapital	0.00014	-0.000123*	0.000109**	0.000294***
	-0.000126	-6.50E-05	-5.48E-05	-0.000103
socialcohesion	8.70E-05	6.81e-05*	-0.000111***	-0.00200***
	-7.16E-05	-3.72E-05	-3.61E-05	-0.000271
GiniIndex	-0.0603***	-0.00783	-0.0358***	0.0702***
	-0.0228	-0.00916	-0.00861	-0.0123
environmentalindex	0.0454***	0.0200***	-0.00603	0.0011
	-0.0131	-0.00489	-0.00462	-0.00702
Constant	-3.065**	-0.952*	1.305***	-2.167***
	-1.43	-0.532	-0.477	-0.647
Observations	483	483	483	483

Table 3. Summary of probit analyses on each rank group.

Top-tier smart cities distinguish themselves from cities not as smart by scoring high on the environmental index and scoring low on the Gini Index. This shows that after a certain point of development in human capital, social cohesion and time required to start a business, further progress in these areas will not significantly increase the smartness of a city. Cities reaching these thresholds should focus on sustainability and inequalities. Indeed, the difference between a rank one and a rank two smart city, is that the rank one smart city focuses on developing new sustainable processes and including them in its infrastructure. Moreover, the rank one smart city also manages to reduce wealth disparities more than rank two smart cities.

Surprisingly, the indicators for an innovation-friendly environment are not significant for the smartest cities. This means that innovation is not a crucial factor for high levels of smartness. The smartest city might be less innovative than a rank 2 smart city. A possible explanation for this is that after a certain point, the difference in the speed to which innovations come to the market is to insignificant to give a city a major competitive advantage. Another explanation for this is that the smartest cities are also the ones that are the most connected globally (Walls and Stavropoulos, 2016). Economic openness is a very important factor for smart cities: cities that are globally open are the smartest. It is therefore possible that the rank 1 smart cities are economically open enough to have access to the latest innovations without having to produce them themselves.

The results for rank 1 smart cities are not very conclusive in terms of verifying the hypotheses. Hypothesis 1 is rejected as none of the indicators for an innovation-friendly city are significant. An innovation-friendly environment is not significantly important for the smartest cities. The second hypothesis is rejected although one of the indicators for a social dimension of the city is significant. The Gini Index is significant, but the social cohesion indicator is not. As a result, the second hypothesis cannot be fully rejected, it is unclear if social peace and comfort is a fundamental determinant of smart cities or not. Finally, the third hypothesis cannot be rejected: indeed, the smartest cities have higher scores on the environmental index than other cities, which means that sustainable cities are more likely to be the smartest.

Rank 2 smart cities are not defined through the same indicators as rank 1 smart cities. The time required to start a business and the environmental index are both significant at 99%. The human capital and social cohesion indicators are both significant at 90%. Time required to start a business is, as expected, negatively correlated with the dependent variable. This means that the faster the time required to start a business is, the more likely a city is likely to be a rank 2 city. Human capital is also negatively correlated with rank 2 smart cities. This is surprising because it means that a city with a low level of human capital is likely to be a rank 2 smart city. Even if the results for the first hypothesis are significant, the hypothesis is rejected. Indeed, the human capital indicator should be positively correlated with a rank 2 smart city.

The social cohesion indicator is significant at 90%. It is positively correlated with rank 2 smart cities. This means that cities with a population that feels safe, integrated, and that fights exclusion, is more likely to be a rank 2 smart city. the Gini Index is not significant for rank 2 smart cities. This means that high or low inequalities are not determining factor for rank 2 smart cities. Therefore, hypothesis 2 is not entirely rejected: only one of the two social indicators is significant in the right way.

Finally, the environmental index is positively correlated with the dependent variable. This result is significant. This means that sustainability is also an important aspect of development for rank 2 smart cities. It also means that the third hypothesis cannot be rejected.

Overall, important features of a rank 2 smart city include a focus on the time it takes to start a business, which should be relatively low. An important care towards social cohesion is also a feature of rank 2 smart cities. Finally, like rank 1 smart cities, rank 2 smart cities also give a lot of importance towards the environment and try to transform their economic activities towards a sustainable one. There is an unexpected and illogical result: the human capital indicator is negatively correlated with rank 2 cities,

this means that the lower the level of human capital, the higher the level of smartness for most cities, this result is significant at 90%, showing a relative weak result.

Rank 3 smart cities are also defined by different factors than rank 1 and rank 2 smart cities: all indicators except the environmental index have a significant impact on the dependent variable. Time required to start a business is positively correlated with rank 3 smart cities. This result is significant at 90%. This means that in rank 3 smart cities, it takes more time to start a business than in this sample's average city. Moreover, the human capital indicator is positively correlated with rank 3 smart cities, this result is significant at 95%. This means that it is important for rank 3 smart cities to improve their human capital. This shows that in the early stage of a smart cities, human capital is more important than the time needed to start a business. The first hypothesis is rejected for rank 3 smart cities.

Social cohesion and the Gini Index are both significant at 99%. The social cohesion indicator and rank 3 smart cities are negatively correlated. This means that rank 3 smart cities have less social cohesion than rank 2 and rank 1 smart cities. However, the Gini index is positively correlated with the dependent variable. In other words, disparities are relatively low in rank 3 smart cities. Rank 3 smart cities are characterized as having low social cohesion within their population despite the fact that inequalities are relatively low. The second hypothesis is therefore rejected for rank 3 smart cities.

Finally, the environmental index has an insignificant impact on smart cities in rank group 3. These cities do not focus on the sustainability of their actions nor the environment in which they are located. Since rank 3 smart cities constitute one of the worst type of smart cities, the fact that they do not care much about the environment shows that the third hypothesis cannot be rejected for these cities.

Rank 4 smart cities are very similar to rank 3 smart cities in terms of indicators that have significant effects on them. However, there are some differences in terms of the degree of significance of each indicator. Firstly, the time required to start a business is also positively correlated with rank 4 cities. This result is more significant (at 95%) than for rank 3 cities, which shows a stronger relationship between the two variables. Moreover, the human capital indicator also has a positive impact on rank for cities, this result is also more is also more significant than for rank 3 smart cities, with a significance of 99%. A strong focus on human capital is important in defining rank 4 smart cities. The first hypothesis is rejected for rank 4 smart cities because time require to start a business is positively correlated with these cities.

The social dimension of smart cities in rank group 4 is very similar to rank 3 smart cities. The only difference is in the magnitude of the effects, which is not observable in a probit model. The social cohesion indicator and the Gini index are both significant at 99%. Like for rank 3 smart cities, rank 4 cities are negatively correlated with the social cohesion indicator. Moreover, the Gini index is negatively correlated with the dependent variable. This shows that inequalities are an important factor even for the least smart cities in the sample. Like for rank 3 smart cities, the second hypothesis is rejected

Finally, the environmental index for rank 4 smart cities is insignificant. This shows that for these cities, the environment and sustainable development are not priorities. As a result, we cannot reject hypothesis 3 for rank 4 smart cities.

Analysing the validity of each hypotheses for different rank groups of smart cities does not show practical result as to whether these hypotheses are valid for smart cities in general. However, looking at the rank groups case by case is very interesting in terms understanding the evolution of smart cities. This next part studies the evolution of smart development in cities by looking at the different stage of development, which are represented by the four rank groups of smart cities. The aim is to look at how the different indicators evolve through each stage and ultimately show a road map to smart city development.

Firstly, this paper looks at how the importance of innovation-related factors changes through each stage. Table 3 can be used to look at the evolution of these factors: their significance and the sign of their impact. The most striking finding is that nor time required to start a business nor human capital are significantly correlated with rank 1 smart cities. This has been pointed out before: it shows that further progress in innovation is not required from rank 2 smart cities to become rank 1 smart cities. Looking solely at time required to start a business, it is shown that rank 3 and rank 4 smart cities have a positive relationship with this indicator. Both of these indicators are significant, at 90% and 95% respectively. This shows that these cities are characterized a relatively slow start-up environment. However, this result is stronger for rank 4 smart cities. Time required to start a business only becomes negatively correlated with the rank of the city for rank 2 smart cities. This result shows that time required to start a business is an important point of development for rank 3 smart cities that are looking to become rank 2 smart cities and eventually a rank 1 smart city, as for the latter the variable does not have a significant impact.

Now looking at the human capital indicator, it is shown that it becomes less significant through the stages, ultimately being insignificant for rank 1 smart cities. In rank 4 cities, human capital is significantly correlated with these cities at 99%. In rank 3 smart cities, the correlation is significant at 95%. The impact of human capital on these smart cities is a positive one, showing the importance of human capital in the first stages of smart development in cities. For rank 2 smart cities however, the two variables are negatively correlated (significant at 90%). This means that the level of human capital has a decreasing value over the stages of smart development, even having a negative added value for rank 2 smart cities. Smart cities give less importance to human capital and more importance to the efficiency of the start-up process, as they become smarter. This phenomenon may seem illogical as human capital should always be an important point of development. However, it is possible that as smart cities develop, their need for high human capital in large quantities decreases. By definition, smart cities have a large technological component in their production factors. It is possible that after the first two stages, the technological component is so large that it crowds out the need for human capital. A paper written by Johannes Fedderke in 2005 explains that for technological growth to happen, the quantity of human capital is less important than its quality. This is what might be happening for smart cities in this sample: as their growth becomes more technology-based, the need for a large quantity of human quantity decreases.

Based on this analysis, the first hypothesis cannot be rejected. An innovation-friendly environment is important for smart city development. However, the indicators chosen to represent an innovation-friendly environment do not act at the same time. Indeed, human capital seems to be an important factor during the early stages of development of smart cities. Large quantities of human capital are likely to be needed to build the foundations of a technology-based economic growth. Once these foundations are laid out, human capital is less needed in quantity and more in quality. It is also at this moment that it become important for cities to become favourable environment for a start up culture in order to bring innovations to the market quickly.

Secondly, the factors for a peaceful social environment are analysed in their evolution through each development stage. Social cohesion does not seem to be in an important factor in the development of smart cities. However, the social cohesion indicator can be used to identify roughly the smartness of a city. Indeed, both rank 4 and rank 3 smart cities are negatively correlated with the social cohesion indicator, at a significance of 99%. In other words, the least smart cities of the sample are characterized by low levels of social cohesion. A shift happens during the third stage of smart city development (rank 2). Indeed, cities at this stage of smart development have a positive relationship with social cohesion, even if this result is only significant at 90%. However, even if this positive correlation is relatively weak, the level of social cohesion achieved by rank 2 smart cities is enough to

achieve the last stage of smart city development. As a matter of fact, the impact of the social cohesion indicator on rank 1 smart cities is insignificant.

When analysing the evolution of the Gini index over the stages, one can see that it almost always a very important part of smart city development. Rank 4 smart cities are characterized by high inequalities. Indeed, table 3 shows a strong positive correlation between these cities and the Gini index, at a 99% significance level. However, this relationship is reversed for rank 3 smart cities: the Gini index is negatively correlated with these cities, also at a 99% significance level. This shows that rank 3 and rank 4 differ greatly in terms of the wealth disparities of their population. In order to become a rank 3 smart city, rank 4 smart cities must decrease inequalities significantly. The second and third stages of smart development are similar in terms of the inequalities in the cities. Indeed, rank 2 smart cities do not show a significant correlation with the Gini index. In other words, the degree of inequality in rank 3 and rank 2 smart cities is relatively similar. However, rank 1 smart cities show a strong (significant at 99%) positive correlation with the Gini index. This means that rank 1 smart cities have the highest degree of equality in their population. To become a rank 1 smart city, rank 2 and rank 3 smart cities must become even more socially equal.

Based on this interpretation, the second hypothesis is rejected. Indeed, it seems that equality is much more important than cohesion. The social cohesion factor can be useful to identify the level of smartness of the least smart cities, however, it is never a strong positive factor of smart development for cities. On the other hand, the Gini index is very useful in identifying degrees of smartness and is also an important point of development at almost every stage. There are three levels of Gini index values over the four development stages. This shows that cities must always work on decreasing their level of inequality in order to become smarter. This does confirm the importance of the social dimension in the development of cities. However, it is not enough to verify the second hypothesis: a social peaceful atmosphere is not necessary for cities to become smarter.

Finally, this paper looks at the environmental dimension of smart cities, and how it evolves through the different stages of smart development. There are two main phases in the development of sustainability. During the first two stages (rank groups 4 and 3), sustainability and the environment are not focus points for the government or municipalities. Table 3 shows that the environmental is not significantly correlated with rank 3 and rank 4 smart cities. However, there is a strong positive relationship between rank 2 smart cities and the environmental index. This result shows that the environment and sustainable processes become relevant to city governments only once they reach a certain point of smartness. This can be explained by the fact that sustainability, in the studied period, was not a top priority for city development; the economy, employment, and equality were more

pressing issues. Therefore, city governments could only focus on developing sustainable processes once the more pressing issues were solved. In rank 1 smart cities, the environment and sustainability are even more important. Indeed, rank 1 smart cities and the environmental are positively correlated, with a significance level at 99%

These results enable the verification of the third hypothesis, as it cannot be rejected. Indeed, the results show that the environment index becomes more and more important through the stages of smart development. Even if initially (first and second stages), environmental issues are not important and sustainable processes are not developed, they become necessary for the later stages. It is even one of two significant factors for the last stage of smart development.

The different profile of smart cities are as follows:

- Rank 4 smart cities are characterized by a slow start-up environment and a relatively high level of human capital. Moreover, cities in this category display a low level of social cohesion and high inequalities. Finally, rank 4 smart cities do not care much for the environment and issues tied to it.
- Rank 3 smart cities are also characterized by a slow start-up environment and a relatively high level of human capital. Social cohesion in these cities is also relatively low, however there is large improvement on inequalities. Rank 3 smart cities also do not care much for the environment and issues tied to it.
- Rank 2 smart cities are very different from the first two profiles. These cities display a much more start-up-friendly environment but a lower level of human capital. Most likely due to technology crowding out the need for human capital. Moreover, these cities are characterized by a slightly higher level of social cohesion. Furthermore, rank 2 smart cities give a lot of importance to the environment and issues tied to it.
- Rank 1 smart cities, or the smartest cities, are not very different from rank 2 smart cites. There are two differences. The first one is that inequalities have been reduced drastically compare to rank 2 smart cities, with a large importance given to the Gini index. Moreover, rank 1 smart cities give even more importance to the environment and issues tied to it than rank 2 smart cities. This may be explained by the fact that in this ranking, the smartest cities are also the most densely inhabited but also the most developed, (London, Tokyo, New York) making them big polluters. As a result, decreasing their environmental footprint is one of their main goals.

LIMITATIONS:

The results presented in this paper are constructive in the way that they show a road map to the different development stages of smart cities. However, this research has limitations

The first limitation of this paper is that the hypotheses are broad, but the variables used to test them are few. For example, the innovation-friendly environment is tested with human capital and the time to required to start a business. And as argued earlier, these variables should give an approximation of the degree of innovation in a city, however, they are probably not enough. For starters, a variable showing the innovation rate itself would be better. Variables showing information such as the government aid to research and development, the number of new patents/copyrights, or the number of new start-ups in a period, could increase the testing accuracy of the first hypothesis. This paper has concluded that the first hypothesis could not be rejected, and that the two variables used to test the hypothesis acted sequentially: human capital is very important at first and then time required to start a business is. One possible interpretation is that innovation is important in smart cities as a strong human capital force will lead to a start-up-friendly environment, and therefore innovation. However, these results can lead to other interpretations, a short time needed to start a business means that it is relatively easy for entrepreneurs to start a business, but it does no necessarily mean that they will do it. Even with a short time required to start a business, there may not be a lot of new start-ups every year. Due to the limited number of available variables for innovation, this paper makes assumptions in order assess the validity of the first hypothesis.

The same thing goes for the second hypothesis: the fact that a socially liveable city has more chances of being smart. Indeed, the Gini index and social cohesion are assumed to be enough to assess the social liveability of a city. And according to the impacts of these two variables on smartness, a city is deemed to be socially liveable or not. However, there are other parameters to social liveability. One of them for example is the crime rate, the other can be government expenditure for public goods, another one could be the housing price. These are all factors that contribute to a socially liveable atmosphere and to inequalities. However, just like for the first hypothesis, the scarcity of available variables forces assumptions to be made. In this case, it is that social cohesion and inequalities are sufficient to assess the social liveability of a city. Therefore, one of the limitation of this research is that the indicators used to test hypotheses 1 and 2 may not be comprehensive enough to assess the validity of the hypotheses.

The environmental index however should be a good indicator for the third hypotheses. However, there is a problem with this indicator as well. The dataset gives an extensive rank of variables for many cities. However, the variables are defined; there is no description about the variables. It is not possible

to know how the environmental index is measured nor what it represents exactly. The same thing goes for the human capital indicator and the social cohesion indicator. As a result, this paper interprets these variables in a very general sense. The paper has to assume that these variables measure their data on a scale where there is a positive relationship between the scale and the actual value of the indicator. For example, it is assumed that a score of 10 on the social cohesion indicator is worst than a score of 500, the same goes for the human capital indicator and the environmental index. In this paper it is assumed that the environmental index is comprehensive of the different aspects of environment care and sustainability, however, it is impossible to know what the environmental index actually measures. Moreover, there are many missing values for the environmental index, as shown in table 1: only 487 observations are indicated out of 1134 possible. The environmental index of the studied cities was not published every year making it hard to analyse its progression over the studied period of time.

There is one more limitation about the data. The ranking of cities in terms of smartness has been made using the methodology proposed by the Centre for Globalization and Strategy. This is one method out of many. There are many other rankings that use different methodologies, as a result, the smartest cities in these ranking may not be the same ones as the smartest cities in other rankings. This whole study is based on a particular ranking, which is a bias. The results would not necessarily be the same if another ranking was used as proxy.

CONCLUSION

This paper has identified the most important components of smart city development. The first one is technology. Technology has been present in smart city definitions since this concept was first invented. The use of ICTs (Information and Communication Technologies) is highlighted in most definitions because they have enabled faster communication between different systems. The IBM reports illustrate this phenomenon well. New technologies and the adequate use of the information they are capable of gathering are the main component in the word ‘smart’. Instrumented, interconnected and intelligent are the key words of a smart use of technology: a city needs to be equipped with ICTs that can gather data in real-time, they need to create a sharing platform for the information gathered by ICTs, and finally they must use this information to optimise services and production processes. The second component of smart cities is the social dimension. This part refers more to the moral values that a city should embody. As pointed out by Mumford (1937), a city is before anything else, a place for people to live, every other aspect of a city are consequences of interactions between people, therefore, a city’s inhabitants are its most valuable (morally but also

economically) most important resource. Following this line of thought, this paper considers that increasing the quality of life of its citizens should be a city government's primary goal. Finally, this paper considers that the environment is one of the most important challenges that we face today, and sustainable development is the most viable solution. More and more people are becoming aware of the negative consequences that our cities have on the environment, it is therefore urgent that cities take actions to lessen their environmental footprint. This is why the environment is the third and final component of smart city development, in this paper.

To summarize: technology enables progress in a smart way, quality of life should be a city's main concern, alongside its impact on the environment. This makes up the three main points of this paper: technology, social liveability, and sustainability.

The first hypothesis of this paper is: cities that have an innovation-friendly environment are smarter. This statement could not be rejected with the presented results. Indeed, variables used to study innovation-friendliness had significant effects on city smartness. Time required to start a business had a significant negative impact on city smartness in the later stages of smart city development. And human capital had a significant positive impact on smartness in the first stages of smart development. These results point toward an important part of innovation in the development of smart cities.

The second hypothesis of this paper is: a city that is more socially liveable is likely to be smarter. This hypothesis is tested through two indicators: social cohesion and the Gini index. The results of the probit analysis enable the rejection of the hypothesis. Indeed, only the Gini index has the predicted impact on smartness: smarter cities have a lower score on the Gini index. However, the social cohesion index is not a significant factor of smart cities. Therefore, this paper concludes that social liveability is not one of the most important factors for smart cities.

Finally, the third hypothesis of this paper cannot be rejected: the environmental factor is important in the development of smart cities. The results of this research have shown a positive relationship between the environmental index and smartness in cities. Cities that take care of their environmental impact become smarter.

REFERENCES

Barrionuevo, J.M., Berrone, P., Ricart, J.E. (2012). SmartCities, Sustainable Progress. *IESE Insight. 14*(3). 50–57.

Benhabib, J., & Spiegel, M. M. (1994). The role of human capital in economic development evidence from aggregate cross-country data. *Journal of Monetary economics*, *34*(2), 143-173.

Caragliu, A., Del Bo, C., Nijkamp, P. (2011). Smart Cities in Europe. *Journal of Urban Technology, 18*(2), 65-82.

Cretu, L. (2012). Smart Cities Design Using Event-driven Paradigm and Semantic Web. *Informatica Economica. 16*(4), 57–67.

Data Team (2017, November 8). In much of sub-Saharan Africa, mobile phones are more common than acces to electricity. *The Economist.* Retrieved from: https://www.economist.com/graphic-detail/2017/11/08/in-much-of-sub-saharan-africa-mobile-phones-are-more-common-than-access-to-electricity

Durkheim, É. (1897). Le suicide [suicide]. *Paris: Felix Alcan*.

Dirks, S., Keeling, M. (2009). A vision of smart cities. *IBM Institute of Business Value*. http://www-31.ibm.com/solutions/cn/government/downloads/GBE03227USEN.PDF

Eindhoven gets the first 3D-concrete printing housing project (2018). Retrieved from: https://www.tue.nl/en/university/news-and-press/news/eindhoven-gets-the-first-3d-concrete-printing-housing-project/

Eger, J. (2003). *The creative community*. San Diego State University, San Diego: White paper on cities and the future.

Fedderke, J. W. (2005). *Technology, human capital and growth* (No. 27). Economic Research Southern Africa.

Giddings, B., Hopwood, B., & O'brien, G. (2002). Environment, economy and society: fitting them together into sustainable development. *Sustainable development*, *10*(4), 187-196.

Giffinger, R., Fertner, C., Kramar, H., & Meijers, E. (2007). City-ranking of European medium-sized cities. *Cent. Reg. Sci. Vienna UT*, 1-12.

Graham, S. (2002). Bridging urban digital divides? Urban polarisation and information and communications technologies (ICTs). *Urban studies*, *39*(1), 33-56.

Harrison, C., Eckman, B., Hamilton, R., Hartswick, P., Kalagnanam, J., Paraszczak, J., Williams, P. (2010). Foundations for Smarter Cities. *IBM Journal of Research and Development. 54*(4), 1-16.

Hjorth, P., & Bagheri, A. (2006). Navigating towards sustainable development: A system dynamics approach. *Futures*, *38*(1), 74-92.

Hollands, R. (2008). Will the real smart city please stand up? *City. 12*(3), 303-320.

International Institute for Sustainable Development. (2018). Retrieved from: http://www.iisd.org/topic/sustainable-development

Lombardi, P., Giordano, S., Farouh, H., Yousef, M. (2012). Modelling the Smart City Performance. *Innovation: The European Journal of Social Science Research. 25*(2), 137–149.

Marsal, L., Colomer, J., Melendez, J. (2014). Lessons in urban monitoring taken from sustainable and livable cities to better address the Smart Cities initiative, Technological Forecasting and Social Change. *Technological Forecasting and Change. 90*(PB), 611-622.

Mumford, L. (1937). *What is a city?* New York, New York. Architectural Record. ADD CITY

Porter, K. (2017, March 13). Making Canada's Capital a 'Smart City'. *Canadian Broadcasting Corporation.* Retrieved from: https://www.cbc.ca/news/canada/ottawa/smart-city-ottawa-gatineau-conference-1.4019918

Saiidi, U. (2017, February 9). How smart cities are building the future. *CNBC.* Retrieved from: https://www.cnbc.com/2017/02/09/how-smart-cities-are-building-the-future.html

Smith, S., Jonze, S., and Moretti, E. (2018). *The Third Industrial Revolution: A Radical New Sharing Economy* [Motion Picture]. United States: Vice Impact.

The World Bank. (2014). Urban Population (%of total). Retrieved from: https://data.worldbank.org/indicator/SP.URB.TOTL.IN.ZS?end=2016&name_desc=false&start=2000

Tieman, R. (2017, October 26). Barcelona: Smart city revolution in progress. *Financial Times.* Retrieved from: https://www.ft.com/content/6d2fe2a8-722c-11e7-93ff-99f383b09ff9

Unknown. (2017, March 29). NUS to train 2,000 Singapore civil servants in data science annually. *Channel News Asia.* Retrieved from: https://www.channelnewsasia.com/news/singapore/nus-to-train-2-000-singapore-civil-servants-in-data-science-annu-8595416

Wall, R. S., & Stavropoulos, S. (2016). Smart cities within world city networks. *Applied Economics Letters*, *23*(12), 875-879.

Washburn, D., Sindhu, U., Balaouras, S. T. E. P. H. A. N. I. E., Dines, R. A., Hayes, N. M., & Nelson, L. E. (2010). Helping CIOs understand “smart city” initiatives: defining the smart city, its drivers, and the role of the CIO. Cambridge, MA: Forrester Research. *Inc. Retrieved June 26*, 2018.