Big, Thick, Small and Short - The Flaws of Current Urban Big Data Trends

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The last decade of the 20th century, as the internet emerged, saw a data revolution. Relatively cheap digital storage and over 1.5 billion gigabytes of available data that could now be used. This also created new challenges; new types of data, coined in 2001 as "Big Data" (due to its three-dimensional characteristics): Volume, Velocity and Variety (Laney, 2001), has to be managed differently. Many cities and city planners hailed the new revolution as the ultimate solution for urban problems. Unfortunately, there is little evidence that data centered cities are succeeding in overcoming urban challenges. In fact, there is a growing understanding that in order to infuse data centered decision making, specifically in urban planning, new models and processes, designed by and for cities are needed. This article examines the origins and the evolution of current Big Data and Smart City trends, from the development of Forrester's System Dynamic Model, through the emergence of the data corporations and the introduction of the Smart City Model. The analysis depicts how the Big Data actors determine the framing of urban data utilization and alternate ways of collecting and utilizing data for urban management and planning, more in tune to the needs and features of cities in the 21st century.

Keywords: *Big Data, System Dynamics, Smart city, Thick Data, Urban Dynamics, Urban Planning, Civic Engagement*

In recent years, 'smart city' has become one of the terms commonly used by mayors and managers to present their advanced, innovative agenda and activities. Similarly, as data has been coined 'the new oil', cities have been embracing sensors and big data for the benefit of better-informed city leaders and optimization of urban services. However, there is little evidence that these investments actually contribute to reducing urban stresses or enhancing economic growth for all. One of the main reasons for this is the over-reliance on big data and lab-based concepts, which are unsuitable for most urban scenarios. While it is true that evidence-based management may improve our cities, the path chosen by many cities since the beginning of the smart city movement has echoed general technological advancement, fit for

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commercial, scientific and industrial arenas, rather than creating new models and processes designed for cities and based on local needs and policies.

This article examines the origins and the evolution of current big data and smart city trends, focusing on the historical role of IBM and the theory of System Dynamics in determining current flawed urban data analysis. The article proposes a more feasible process of collecting and utilizing data for urban management and planning, more in tune with the needs and especially the capacities of 21st century cities and communities.

IBM & CISCO'S FIRST STEPS

Data has been utilized in cities as early as 1849, when William Farr created a data-based research, examining the urban aspects of the cholera outbreak, but only in the 20th century did data become part of urban decision making. In 1974, Los Angeles published its data based urban analysis of Los Angeles (Los Angeles Community Analysis Bureau, 1974), created to improve housing decisions (Vallianatos, 2015), and RAND institute assisted NYC in optimizing fire response between 1967-1974 (Flood, 2010). However, our focus on the role of IBM in the current era of smart cities and urban data strategies is a result of interest by commercial tech vendors, imitated by IBM, in the beginning of the 21st century.

In 2008, IBM launched the 'smarter planet' initiative as a new strategic agenda for progress and growth amid the global economic crisis, through "instrumentation, interconnectedness and intelligence". The vision was to "inject" computational powers into everything as a system of systems – an internet of things (IoT) producing oceans of raw data and processing it through IBM's tools. As part of this strategy, IBM launched in 2009 the Smarter Cities campaign, proposing a "comprehensive approach to helping cities run more efficiently, save money and resources, and improve the quality of life for citizens" (IBM, no date).

This goal was attained by introducing a new analytics software and services, named 'System Dynamics for Smarter Cities':

> "…To help planners and policy makers better understand and manage the dynamic behavior of cities…an interactive model that allows leaders to observe how the core systems of a city – such as the economy, housing, education, public safety, transportation, health care, government services and utilities – work together and affect one another (IBM, 2011)[1].

However, while Cisco launched a similar initiative only a year after IBM[2], for several years both competed as the smart city leaders[3]. Although, later, other tech companies followed, the IBM model is the most dominant smart city approach, based on a controversial application of business and industrial theory of MIT professor Jay Forrester, to urban and social issues since the late 1950's.

FORRESTER AND URBAN DYNAMICS – FROM U.S. NAVY SIMULATORS TO CITIES

Jay W. Forrester, an MIT professor (1918-2016), pioneered computational simulations, designing computer-based aircraft simulators for the U.S. navy, which evolved into the design of the "whirlwind digital computer", the first digital computer, built for experimental development of military combat information systems. This computer was a key component in the development of the U.S. Semi-Automatic Ground Environment (SAGE) in the later 1950's, built and integrated by IBM. SAGE coordinated data from many radar sites and processed it to produce a single unified image of the airspace over a wide area to enable coordinated U.S. air defense during the cold war (Forrester, 1989). When Forrester left engineering to accept a post at Sloan School of Management in MIT, his research and activities were focused on exploring this idea of coordinated systems, or 'system of systems', by applying computing and mathematical models to understand complex business and industrial systems and their potential flows and actions focused on predicting possible outcomes.

This model, developed in the late 1950's, was called System Dynamics, and published initially in 1958, as an article called 'Industrial Dynamics – A Major Breakthrough for Decision Makers' in Harvard Business Review (Forrester, 1978). Forrester recalls:

> "For that article I needed computer simulations and asked Bennett[4] just to code up the equations so we could run them on our computer. However, Dick Bennett was a very independent type. He said he would not code the program for that set of equations but would make a compiler that would automatically create the computer code. He called the compiler "SIMPLE," meaning "Simulation of Industrial Management Problems with Lots of Equations. Bennett's insistence on creating a compiler is another of the important turning points; it accelerated later modeling that rapidly expanded system dynamics" (Forrester, 1989).

While this action became one of the accelerators of business oriented computer simulations, it also gave place to the future over-reliance on lab-based policies, and structuring of problems and challenges so that they may fit into simplified equations, as in the future evolution of system dynamics into urban and social issues.

In 1968, the Mayor of Boston, John Frederick Collins, was invited to take a post of visiting professor of urban affairs at MIT. As the occupier of the office next door to Forrester's, they began discussing urban problems. Forrester decided to explore the potential of his system dynamics model to solve urban complexities. In 1969, Forrester published the book *Urban Dynamics*, which considered how system dynamics could be used to understand America's urban crisis (Forrester, 1969).

> "The problems of our aging urban areas are examined here by using recently developed methods for understanding complex social systems...the nature of the urban problem, its causes, and possible corrections are examined in terms

> of interactions between components of the urban system" (Forrester, 1969, ix).
>
> "Our social systems are far more complex and harder to understand than our technological systems. Why, then, do we not use the same approach of making models of social systems and conducting laboratory experiments on those models before we try new laws and government programs in real life" (Forrester, 1971, 226).

Through repeated computer simulations, Forrester analyzed the changing ratios of (generic) critical urban development factors such as population, housing, and industry, and showed how the changes would affect a city's growth.

Forrester believed that systems seek to be in equilibrium, and therefore actions lead to "Boom & Bust Effect" as the city seeks to regain its equilibrium. Based on these lab-based models, he stated (gaining controversy and negative attention) that low-cost housing and job training are wrong strategies, because they will lead to other problems such as overpopulation and greater tax demands on the underemployed, therefore they will create a vicious cycle of city failure.

While laboratory models may have enabled crystallized answers to urban problems, real-life trials in the 1970's (mostly in cities close to the MIT Urban Dynamics Lab), were rejected by governmental departments, city officials and planners. Louis E. Alfeld, the director of the Urban Systems Lab at the time, wrote about these trials, twenty years later, explaining the failure due to lack of interest and conservatism:

> "the members [of the HUD committee] had neither the time nor the inclination to study system dynamics…Since the committee, trained in traditional econometric modeling, would not accept any of the model relationships without support from solid literature references or published data, they essentially rejected everything" (Alfeld, 1995a, 199).

But Alfeld also admitted that the models lacked flexibility and lacked a robust connection to the 'field':

> "… by attempting to rebalance all of the forces at a single stroke, we placed ourselves outside the bounds of political realism. Acceptable answers, alternative trade-off options, and consensus building (instead of criticism) could have produced a successful outcome (Alfeld, 1995b, 204).

This Notion was echoed in Forrester's own recount in 1993 of the history of urban dynamics.

> "...There is an unwillingness to accept the idea that families, corporations, and governments belong to the same general class of dynamic structures as do chemical refineries and autopilots for aircraft… The concept of a system implies that people are not entirely free agents but are substantially responsive to their surroundings" (Forrester, 1993, 7).

Lacking urban planning or social sciences background, the main error of Forrester's urban dynamics was the over-simplification of people and communities, comparing urbanism to industry and human decision to factory assembly lines.

While machines and financial systems seek equilibrium, people and communities seek joy, satisfaction and gratification.

Forrester's wish to identify exact numbers and equations for each urban challenge may have enabled simulations and "right's and wrong's" ((later echoed in the popular game SIMCITY (Starr, 1994), and in current trends of City-information Modelling)). It was based on the idea that people are not "free agents" and therefore their actions may be predicted and influenced. People are indeed "social animals" preferring to be part of a group or a community, they respond to their surroundings, but this response is emotional, rather than mechanical. People *are* free agents, but they may choose to be part of a structured community, while still making their own decisions, and therefore are not necessarily predictive or measurable, as urban dynamics suggests.

One of the reasons that the real-life trials of urban dynamics failed was lack of evidence and sufficient data to engage planners and civic leaders. But the fact was that when IBM returned to urban dynamics with the "Smarter Cities" campaign 40 years later, they made the same mistakes, even though they had access to larger and more complex data. This flawed structuring and simplification of cities and people, originating with IBM, determined that cities and people are part of a "structure", and caused the downfall of Forrester's theory and will probably fail currently, 40 years later.

IBM, DATA AND THE (NEW) SYSTEM DYNAMICS

The last decade of the 20th century, as the internet emerged, saw a data revolution: relatively cheap digital storage and over 1.5 billion gigabytes of available data that could now be used. This also created new challenges; new types of data, coined in 2001 as "Big Data" (due to its three-dimensional characteristics): Volume, Velocity and Variety (Laney, 2001), has to be managed differently.

At the time, IBM was in the midst of shifting the business focus from hardware to software, taking a major role in creating services to manage, "crunch" and analyze data. This new potential to create new knowledge, due to access to data, and the potential of creating "sophisticated analytics and algorithms that could make sense of it all" became the core component in launching the 'Smarter Planet' initiative, IBM's growth strategy in 2008[5]. In 2008, Wired published an inspirational article titled: 'The End of Theory: The Data Deluge Makes the Scientific Method Obsolete' (Anderson, 2008). The article by the magazine's editor in chief, Chris Andersen, proposed Big Data as a substitute to science as we know it:

> "This is a world where massive amounts of data and applied mathematics replace every other tool that might be brought to bear. Out with every theory of human behavior, from linguistics to sociology. Forget taxonomy, ontology, and psychology. Who knows why people do what they do? The point is they do it, and we can track and measure it with unprecedented fidelity. With

enough data, the numbers speak for themselves" (Anderson, 2008).

Andersen proposed to stop using data to improve existing scientific methods, and instead, change scientific methods by relying on new access to large quantities of relevant data. Andersen closes the article by stating: "There's no reason to cling to our old ways. It's time to ask: What can science learn from Google?"

At the same year, 2008, influenced by the financial crisis, IBM sought to create new markets by focusing on government, and introduces the 'smarter cities' campaign. However, contrary to the proposal made by Wired to embrace new scientific models, IBM chose to revive 'system dynamics', hoping to achieve better results than Forrester, through cheaper and more sophisticated data collection, storage and analysis, introducing a new urban dynamic which is more responsive and evidence-based.

In 2011, IBM announced their first smart city partnership with the city of Portland, introducing the 'system dynamic for smarter cities platform' as "an interactive model of the relationships that exist among the city's core systems" (IBM Press Release, 2011).

> "…a simulation model and decision support system for city leaders with predictive capabilities, the model offers the ability to create countless what-if scenarios that show the impact including positive and negative consequences then a proposed policy decision could have on the city and its citizens." (IBM, 2011)

In Fast Company magazine, Greg Lindsay criticized the ambitions of the platform and over-reliance on data and algorithms, in an article titled "IBM Partners with Portland to Play SimCity For Real":

> "Systems Dynamics for Smarter Cities, tries to quantify the cause-and-effect relationships between seemingly uncorrelated urban phenomena. What is the connection, for example, between public transit fares and high school graduation rates? Alternatively, obesity rates and carbon emissions? To find out, simply round up experts to hash out the linkages, translate them into algorithms, and upload enough historical data to populate the model. Then turn the knobs to see what happens when you nudge the city in one direction". (Lindsay, 2011)

The 2011 Portland campaign which was to be part of Portland's strategic plan, failed, as Forrester's 1970's real life trials, to transfer the mathematics and aggregation of numerous datasets to real urban impact. Anthony Townsend, in his influential book 'Smart Cities: Big Data, Civic Hackers, and the Quest for a New Utopia', explained:

> "IBM developed a computer model of Portland that dwarfed Forrester's 'System Dynamics for Smarter Cities', as the apparatus was blithely named, wove together more than three thousand equations. Forrester's had used just 118 (only 42 of which, a subsequent analysis determined, really shaped the results). On a website used to interact with the model, diagrams reminiscent of those in Urban Dynamics dissected the city into a spaghetti-like tangle of interacting variables… a spiderweb of relationships that quickly ballooned

> to over seven thousand equations (a number that was deemed too complex), was pruned back to six hundred (too simple), and then eventually built back up to the roughly three thousand contained in the final revision." (Townsend, 2013, 80)

While Forrester's model gave debatable predictions, the new IBM's model, with much more data and algorithms, produced even more simplistic predictions such as linking cycling to the reduction of carbon emission and obesity. While the results may have been a tactical marketing decision to improve municipal acceptance, they failed to influence more cities to choose the system.

> "The challenge for models like these in the future will invariably lie in better balancing the value gained (which is still too small) with the effort required by the city to maintain and operate it (still too high)"(Townsend, 2013, 85).

However, although IBM's gamble on complex data analytics failed, IBM's primacy in smart cities led to the fact that practically every smart city project since built upon this experience, using, collecting and analyzing big data that add little or no value.

THE PROBLEM WITH DEFINING BIG DATA

One of the primary problems with data and cities is that the term Big Data is incorrectly used, mistaking any 'data' as 'big' and every analysis of data as big-data analytics. The result of this branding of data is that there is too little discussion about the role of data in civic management, what kind of data is essential and how it can be managed.

From the technical perspective, big data, as coined by Doug Laney in 2012 at Gartner, related initially to the challenge of managing and using vast amounts of available data (the three "V"s)[6]. Over the years, more "V"s were added (in 2019 researchers identifies up to 51 "V"s (Rijmenam, 2013), among them, four relate to the urban context:

- Veracity and Variability – representing variation in data flows and data sources imposing a need to clean, validate and transform data from different sources to make sense;
- Visualization – making vast amounts of data easy to understand, read and act upon;
- Value – representing a variance of importance between certain data volumes.

Big data, according to Laney (, relates to amounts of data, but size is not the main factor. The main issue in Big Data is the complexity of collecting, managing and validating the data. This complexity is the largest barrier to making sense of this data, towards real value creation. While many cities still see Big Data mainly as large data-sets that may be used to understand current and future trends, they miss the real opportunity to use data as part of urban policies, neglecting a discussion regarding what data needs to be collected (and how) and how such data may influence decision making and urban sustainability and resilience. This size-based definition has been influenced by tech vendors such as IBM and, by national and global policy makers that need statistically oriented global data, rather than localized complex information.

In 2017, The World Bank published a report on big-data and government, defining Big Data as "the exponential growth of data, particularly the data flowing from ubiquitous mobile phones, satellites, ground sensors, vehicles and social media" (World Bank, 2017, 1). The report explains the potential of Big Data in service delivery, policy-making and citizen engagement, and calls for governments to be active by producing more data sets, consuming Big Data to create responsive governments, and facilitating usage and creation of Big Data by investing in research and stewardship as well as promoting relevant strategies.

However, the World Bank's definition of Big Data focuses on growth (in size) of data and the expressed interest and motivation for more responsive governments by collecting, storing and analyzing big amounts of data, to enable statistic and comparative data (between cities and states), to ensure transparency and financial governance. Such focus is relevant for global governance but has less value for national governments and very little value for local authorities, since it focuses on large quantities instead of depth of data essential for actions.

While global organizations need data to compare between countries and regions, to define how and where to finance infrastructure, central governments need data to manage nation-wide infrastructure loads (such as energy, transportation etc.) and to enable regional execution and budgeting of such structures. City leaders, need data to surmise real demands based on localized data, such as population per bus stops, how many people do not have alternatives to public transportation due to age, disabilities or any other reason, or suffer from energy or digital poverty, and what actions are needed (and where) to reduce such exclusion as well as encourage behavioral change. While cities need to develop inclusive solutions that may call for tailor-made actions due to difference in culture, and demography of socio-economic backgrounds, national governments chose nation-wide strategies that rarely differ between cities and regions.

Due to these differences, it may be wrong to copy data trends – either from the business sector that seek big data to enable continuous calibration of the equilibrium of systems through complex and varied data sets, or from national or global bodies that seek large data to enable balanced management and transparency through large quantities of statistical data. In many ways, needs for data in cities are similar in complexity to the needs of businesses, as the lack of correct data is crucial in both. However, while businesses are privately owned and have to answer only to the law and stock owners, data collected, managed and used by local authorities greatly impacts human lives and welfare, economic resilience of the local businesses and the future of the environment within city boundaries.

As cities are civic entities, they are obligated to their stakeholders and community, and need to create guidance to ensure these strictures, the EU translated this dilemma into regulations to guide data providers[7]. In 2013, the city of Copenhagen, decided to invest in the creation of a marketplace for the exchange of public, and private sector data. The Hitachi Corporation won the tender for this enterprise and worked together with the city and with the region in order to create a cooperative and transparent data platform. The report of the project identifies three key drivers for success:

- Start with the use case, as it is key to engage the data community that will use the data;
- Create a data competence hub, where the data community can meet and get support;
- Create simple standards and guidelines for data publishing (Municipality of Copenhagen, 2018).

This was an innovative approach to test the readiness of the market to deliver new data-sharing solutions and to establish regulations and data security measures. Despite the experience and success of cities such as Copenhagen to provide effective data management, smaller, and less prosperous cities (that are less attractive for global companies such as Hitachi), may accede to private sector's 'data miners' that could abuse the public interest and substantially compromise the value of such data.

Due to these challenges, biases and financial and organizational burdens, it is essential that cities create their own urban data strategy. This will be aimed at defining what should be collected and managed, how and by whom, based on the unique character and capacity of the local authority, as well as the culture, level of trust and collaborative opportunities within the city. Such strategy should enable a clear view of what *really* has to be collected (and where) and what are the prices to be paid (which are worthwhile for the city and its residents). As costs and logistics are large obstacles to urban data based governance (as well as the consequences of managing such complex data), there is another, much less intrusive and costly approach to data that should be considered - Thick Data.

THICK DATA

While Big Data delivers answers in 'big numbers' that facilitate understanding of "what" happened, it constantly fails to explain "why" an occurrence occurs. Big Data can indicate exactly where car accidents happen, or in which street in the same neighborhood families prefer to live; it will not reveal the reason why this occurs. System dynamics as well as current day artificial intelligence (AI) tools can predict future urban patterns that can propose and influence urban decisions based on algorithms or machine learning, but they fail to reveal the urban dynamics that compound the situation. Urban situations are based on a complex choreography between cultures, needs, places and trends, which may vary over time, age group or political affiliations (going generations back). Predictive analytics are limited in predicting the preference of individuals or a community, even if the best historical data has been collected and analyzed. While such data may generate a large part of the answer, it misses the qualitative aspects that complete the picture needed for urban decision makers and planners.

Tricia Wang, a global tech ethnographer, was one of the first to coin the term “Thick Data”, following her research for Nokia in China in 2009 (Wang, 2013). Wang spent time with migrants, street vendors and internet café users, talking to them and digging deeply into their stories. She concluded that low-income consumers were ready to pay for smarter phones. Nokia, at the time the world’s largest cellular company, rejected Wang’s conclusions based on the company’s big data of millions of data points, compared to Wang’s 100 participants (what now is known to be Nokia’s big business mistake).’Thick Data’ as Wang defines, is:

> “….a qualitative approach, obtaining ethnographic data that allows to reveal contexts and emotions of the studied subjects. While Big Data requires an algorithmic process usually carried out by statesmen and mathematicians, Thick Data is the ground of anthropologists, sociologists, and social scientists…… Thick Data is the best method for mapping unknown territory. […]. When organizations want to know what they do not already know, they need Thick Data because it gives something that Big Data explicitly does not - inspiration. […]When organizations want to build stronger ties with stakeholders, they need stories. Stories contain emotions, something that no scrubbed and normalized dataset can ever deliver…Thick Data approaches reach deep into people’s hearts. Ultimately, a relationship between a stakeholder and an organization/brand is emotional, not rational”.

This Concept of ‘Thick”, also termed ‘Small’ Data by Danish author and columnist Lindstrom (Lindstorm, 2016), is especially relevant for cities, because it follows the traditional way cities and towns were managed. Mayors met the community at town hall meetings or under the largest tree in the town square and made decisions through conversation, considering public wisdom, culture and intuition. Such social intuition, or the “inspiration” described by Wang, is missing in many of our municipalities as they are engulfed with big data analysis and mechanisms. In the new Big Data era, intuition is substituted for algorithms and lab-based experiments that fail to inspire the community to become part of the solution.

In addition to the qualitative advantage of Thick Data over the unpersonal attributes of Big Data, Thick Data has potential significant importance in encouraging accountability and civic engagement, since it prefers quality over quantity, narratives over dry facts, and therefore reduces bias evident in big numbers, while enabling local social sentiments to be heard. Such, sometimes unique, voices that may have no impact on the result of statistic large scale evaluation, are important in understanding impacts of scenarios and civic action, especially in current day’s task to create more inclusive built environments.

In 2019, 50 years after Urban Dynamics and 10 years after the Smart City Based 'Urban System Dynamics' framework was introduced, the IBM Centre for Business Government published a report, slightly backing off from 'system dynamics for cities', recognizing the need for Thick Data. The report stated that the best practice is actually to reduce reliance on lab-based Big Data and start using "mixed analytics" which can increase accuracy and improve the interpretation by adding contextual knowledge about citizen concerns (Ang, 2019).[8]

IBM's report defines six principles, very different from their previous models, combining Big and Thick data:

1. Big Data is a means to an end, rather than an end;
2. Thick Data can identify unexpected problems or previously unexpressed needs;
3. Thick Data can inform the analysis of big data;
4. Mixed analytics can offer both scale and depth;
5. Applying technology is a social activity, not an isolated technical task;
6. The best solutions are not always high-tech.

CONCLUSION

Thick Data may be the missing part of the puzzle to enable "smart"' but inclusive and sustainable cities. As shown, such data depends on the urban community's willingness to share their wishes, beliefs and ideas, an impossible fit without gaining and retaining trust. The Edelman Trust Barometer[9], the most comprehensive study of trust in the world, with over two million respondents, has been measuring trust for the past 20 years in business, government, media, and NGOs. As can be seen in the graph below, out of the four sectors, governments earns the lowest level of trust, 50%. The business sector and NGO's are 8% higher while local governments score 53%. 66% of the respondents stated, "They do not believe that the current leaders will be successful in addressing our challenges", and a similar percentage are concerned that governments do not understand emerging technology enough to regulate it effectively. Evidently, people perceive governments, both local and national, as the controllers of data, but do not trust them to fulfill their role effectively.

Conversely, cities do need data in order to provide better services, improve quality of life and sustainability, not the exact data - but the story connected to a place, combined with the average demography and the needs of each area. This type of data – localized and personalized—is even more dependent on cooperation and trust. While cities around the world such as Tel Aviv, Jerusalem, London, Boston, Paris and others are embracing sub city governance models with formal or informal leaderships, and with new urban prototypes such as "20-minute-city" models to celebrate hyper localism, data may be treated similarly. However, as the Edelman survey proved, people do not trust the city to protect their data, and to hide their identity, therefore the data should be owned and managed by the community itself - sharing only unidentifiable data with municipal entities and platforms.

Community trust, based on shared interests and understanding, may substitute the need for sophisticated data prediction tools. People will be willing to share *thicker* information about themselves in order to provide insights for the common good. Mayors and civic leaders will be able to reduce conflicts and budget biases, as they obtain correct and current demand maps of each community, allowing for better tailor-made resource allocation. Localized data and information networks can be expanded to additional city stakeholders as data becomes more robust and reliable. Producers, suppliers and local economic stakeholders will utilize this type of data to reduce financial risks (and costs) in commerce and business.

Such new databased urban processes call for new strategies, and structures, combined with leadership and trust, to enable sub-urban data networks (including, training, digital infrastructure and co-ownership mechanisms). The impact and value of the data that the community can generate and utilize, will enable real inclusivity, resilience and stability, essential towards responding to our 21st century challenges.

NOTES

1. 'IBM and City of Portland Collaborate to Build a Smarter City', IBM Press release Portland, Oregon, USA - 09 Aug 2011
2. Cisco has launched a data-based carbon emission initiative with the Clinton Foundation in 2006, but launched its commercial 'smart & connected community' initiative only in 2010. https://www.cisco.com/c/en/us/solutions/industries/smart-connected-communities.html
3. Based on Navigant Research Report on Smart City Suppliers, IBM was the leading supplier until Cisco took the lead in 2017. In 2020, Microsoft took the lead of the market with Cisco & Huawei not far behind, and IBM out of the leading 10 companies https://guidehouseinsights.com/reports/guidehouse-insights-leaderboard-smart-city-platform-suppliers
4. Bennet was a computer programmer working for Forrester
5. IBM100 – Smarter Planet, https://www.ibm.com/ibm/history/ibm100/us/en/icons/smarterplanet/
6. https://blogs.gartner.com/doug-laney/files/2012/01/ad949-3D-Data-Management-Controlling-Data-Volume-Velocity-and-Variety.pdf. Laney's 2001 article was later removed from Gartner Blogs and replaced in 2013 with the post "Gartner's Big Data Definition Consists of Three Parts, Not to Be Confused with Three "V"s" (Sicular, 2013)
7. The EU regulations for GDPR require agreement from all data providers before they are used but these directives are not yet accepted globally.
8. This report is a clear change from previous IBM ideology, stated in recent report "Ten Actions to Implement Big Data Initiatives: A Study of 65 Cities"

praising Big Data and complex data rich environments.

9. https://www.edelman.com/trustbarometer

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