Action Design Research in Practice: The Case of Smart Cities

Giovanni Maccani[1,*], Brian Donnellan[1], and Markus Helfert[2]

[1] National University of Ireland Maynooth, Co. Kildare, Ireland
{giovanni.maccani.2013,brian.donnellan}@nuim.ie
[2] Dublin City University, Dublin 9, Co. Dublin, Ireland
markus.helfert@computing.dcu.ie

Abstract. Smart Cities has emerged as an important research challenge among IS researchers in recent years. The grand claims that have been done about the potential of Smart Cities are grounded in a wide range of IT-related artifacts that were designed in theory and/or implemented in practice. Today, due to the growth of the level of knowledge maturity in this context, IS research in this field is more focused on the development of a nascent Smart City theory. The key concepts introduced in literature were collected through an eight-steps systematic literature review [19] and analyzed using [20]'s concept definition matrix. Based on this, this paper aims at reflecting upon research methodologies for conducting IS research in this field, and demonstrates the suitability of Action Design Research [43]. A Smart City research project that successfully used this methodology is also described to further support this statement.

Keywords: Smart Cities, Action Design Research, Systematic Literature Review.

1 Introduction: IS Research on Smart Cities

Smart Cities is more and more acknowledged as a relevant research challenge among IS researchers. The term Smart City was firstly introduced in [1]. In this seminal article the Smart City mission is defined as:

> "*The urban centre of the future, made safe, secure environmentally green, and efficient because all structures are designed, constructed, and maintained making use of advanced, integrated materials, sensors, electronics, and networks which are interfaced with computerized systems comprised of databases, tracking and decision making algorithms*". [1, pp. 2]

However, greater attention by IS researchers started with the grand claims made by IBM [2][3] about the potential for such initiatives. Particularly the authors referred to the introduction of the concept of *"city as a system of systems"* [2, pp. 11]. In other words, their visionary articles aimed at demonstrating the potential value that is expected to be achieved through the application of different ICT solutions across a number of city's core systems, such as Transport, Communication, Water, and Energy

* Corresponding author.

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to mention few. Then, their integration and interconnection would allow the creation of a holistic "system of systems" that is able to embed these city's core systems, and so to enable both a more efficient and effective management of the overall city [4], and a positive impact on its "triple bottom line" (economy, environment, society) [5]. Thus, the grand claims that have been done about the potential of Smart Cities are grounded in a wide range of IT-related artifacts that were designed in theory and/or implemented in practice. For example, their implementation across different city's domains can enable Intelligent Transportation Systems (e.g. [6]), or can increase water (e.g. [7]) and energy supply (e.g. [8]) efficiency, to mention some general instances. In the following years the IS research around Smart Cities significantly changed. In detail, the goals shifted from specific technological problem-solution analysis to more comprehensive studies regarding, for instance, innovative measurement frameworks [9] or overall strategies and business models [10][11]. In other words, from specific instantiation and implementation of software and process solutions, the IS research around Smart Cities is now concerned more with defining operational solutions, and so with structuring a new Smart City theory. In order to study how the research is moving in this way, we adopt Gregor and Hevner's framework [12] that outlines three levels of "contribution types" for Design Science Research (DSR) (see Figure 1). The DSR artifact has different natures [13] and the one that is assumed partially determines the type of contribution to knowledge. Other factors such as the state of the field of knowledge and the academic research conversation to which the research outcome is to be communicated are further variables that might be included when analyzing the nature of knowledge contribution [12].

	Contribution Types	Example Artifacts
More abstract, complete, and mature knowledge	Level 3. Well-developed design theory about embedded phenomena	Design theories (mid-range and grand theories)
↕ ↕ ↕ ↕	Level 2. Nascent design theory—knowledge as operational principles/architecture	Constructs, methods, models, design principles, technological rules.
More specific, limited, and less mature knowledge	Level 1. Situated implementation of artifact	Instantiations (software products or implemented processes)

Fig. 1. Design Science Research Contribution Types [12, pp.342]

In Figure 1, it is clear that the authors predict different levels of contribution types in relation to the level of maturity of the knowledge around the topic (i.e. "*problem maturity*", [12, pp. 344]). As seen, the context of Smart Cities is then maturing and quickly evolved in academic literature since the publication of the seminal articles above mentioned. A plethora of suggestions regarding ICT solutions (artifacts) to make cities "smarter" is available in the literature to date [14]. Subsequently, a fundamental need to reflect on the Smart City concept, its construction and underlying assumptions to enable transparency and new readings was highlighted [15]. In other words, *"cities currently face a problem of standardization of the main building blocks of smart/intelligent cities in terms of applications, business model, and services. Standardization would dramatically reduce the development and maintenance costs of e-services due to cooperation, exchange, and sharing of resources"* [16]. Referring to the left cell in Figure 1, the maturity of the knowledge regarding Smart Cities is growing due the exponential growth of related academic publications. This shift is reflected in a change of the content and of

the focuses upon which IS research on Smart Cities is conducted (from level 1 to level 2 in Figure 1). This paper aims at identifying a suitable research methodology for conducting IS research in the current context of Smart Cities. As a consequence, we conducted a systematic review of the literature (presented in section 2) to investigate the main concepts that IS authors introduced in this field to define what a Smart City is and which are the conceptual elements involved in such initiatives. It will allow us to identify a suitable research methodology (section 3) to systematically drive the research activities in the context of Smart Cities. Finally an example of a Smart City IS research project is provided in section 4, before the conclusions, where the main contributions of this paper are outlined.

2 Smart City Systematic Literature Review

Despite the plethora of suggestions regarding the design and instantiation of IT-related artifacts to improve the city's social, economical and environmental performances, the Smart City concept is still emerging, and the work of defining and categorizing it is in progress [17]. In fact, most of the definitions provided come from individual research needs or perspectives [18]. As a consequence we conducted a systematic literature review (SLR). This process adhered to Okoli et al's 8 steps [19] that are: (1) Purpose of the Literature Review, (2) Protocol and Training, (3) Searching for the Literature, (4) Practical Screen, (5) Quality Appraisal, (6) Data Extraction, (7) Synthesis of Studies, and (8) Writing the Review. Within the following sub sections, all of these steps will be described.

(1) ***Purpose of the Literature Review:*** in our case, this study was conducted to analyze the progresses of the stream of research connected to Smart Cities. Particularly, the main aim of this study is to extract all the relevant concepts that have been used in defining Smart Cities, and which are believed to be its enabler factors.

(2) ***Protocol and Training:*** within this second stage of the process, the specific steps and procedures to be followed have to be detailed. First, the key review questions must be defined. Consistently with the objectives outlined in step 1, two key review questions (RevQ) arose: what does the term Smart City mean? (RevQ1); which are the homogeneous dimensions that fully encompass all the enabler factors of Smart Cities? (RevQ2). The approaches that were followed were similar for both the RevQs. In detail to answer RevQ1 the first step was to collect all the definitions that have been published in literature. In order to systematically analyze these definitions, we defined a common syntactic structure made of different categories. The next step was about the development of a concept matrix, using as guidance the methodology proposed in [20]. Its development allowed us to have a complete overview of what have been said, how many times, and what a comprehensive definition of Smart Cities should include. The same approach was followed for RevQ2. The only difference was the subject under analysis. In fact, the analysis has taken into account all the contributions in which there was a clear attempt of defining and conceptualizing the Smart City concept with dimensions. These attempts can range from frameworks to simple lists of enabler factors. This process was externally validated by experts in the field of Smart Cities, and from experts in systematic literature review within the academic field.

(3) ***Searching for the Literature:*** The requirement for an article to be considered for this study was the presence of the word "Smart City/Smart Cities" either within the abstract, or the keywords, or the title of the paper. The sources of literature collection that we considered were three; in first place we looked at the most important journals' websites following journal rating charts such as the "AIS Basket of 8"; then, open access databases (Google Scholar) and specific subject databases (ACM Digital Library) were also included. In total we collected 908 articles. We then applied first exclusion criteria to titles (e.g. language), and there were 442 articles that were ordered and searched, and considered further.

(4) ***Practical Screen:*** The output of this step has to be a complete list of the literature that is considered for the review. In our case we went through it twice. First we reduced the total amount of articles by reading the abstracts of all the papers we had previously collected. Then, we carefully read all the papers. In particular, we verified their consistency with the two RevQs. In Figure 2 a summary of the process we implemented is provided.

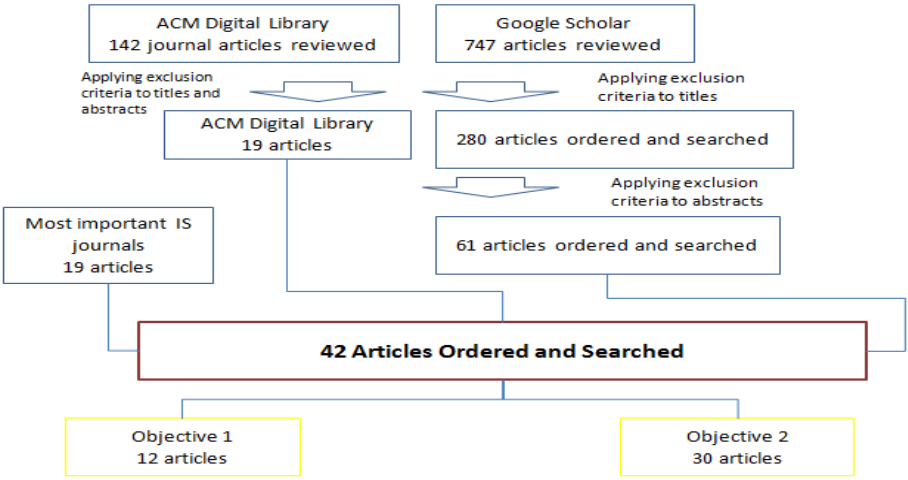

Fig. 2. Literature Selection Process

As a result we considered 12 contributions for answering RevQ1 and 30 for RevQ2.

(5) ***Quality Appraisal***: this step involves a closer examination of the articles in order to assess their quality. However, given the novelty of the topic (almost 95% of the articles were published in the last two years), there were not problems relating to the amount of articles.

(6) ***Data Extraction:*** at this stage, a complete list of articles that comprised all of the materials needed to answer our RevQs was available. Therefore, we isolated the information relating to the two relevant objectives for this study. We listed all of the definitions in a table. We then extracted all the dimensions used to conceptualize Smart Cities. The output of this step was a complete list of relevant concepts from which we could synthesize our study and derive our conclusions.

(7) ***Synthesis of Studies:*** with respect to the definitions, we first looked at the syntax of the sentences. While doing so, we defined a common structure characterized by a number of main areas in which all the concepts that arise from these definitions can consistently fit. Examining the texts of the definitions we then classified at a high level of abstraction the components of such phrases, stating that: "*The Smart City is a [Context] that exploits / uses / leverages / develops an [Infrastructure] with-a-certain / implementing an [Approach] supported by [Factors] to enable [processes] to achieve/ improve / enhance / increase [Goals]"*. In other words, every single key concept that is stated in the definitions is related to one of these six main areas, i.e. context, infrastructure, processes, approach, factors, goals. So, after checking its validity, we've decomposed all the definitions into their key words or notions. Hence, with all the words/notions available, we followed the concept matrix method [20] in which each key word/notion is related to the author and grouped within the category to which it belongs (see Figure 3). After a preliminary investigation of the definition concept matrix, we could infer that a Smart City could be described as an initiative that exploits technologies to deliver "smart" information services aiming at better environmental performances, increase or add efficiencies, and improve city's competitiveness or, in other words, develop the so called Smart Economy [5]. A recurring theme refers to the human/social capital as a key enabler of Smart Cities. However, insights about important innovative approaches [16], and new management and governance principles [21] were still lacking in these definitions.

Then, we went into a greater level of detail aiming at the definition of mutually exclusive and collectively exhaustive areas that fully encompass all the enabling factors of Smart Cities. Based on RevQ2 we developed another concept matrix (already published in [14]) in which all the enabler factors that have been chosen by authors to describe this field were categorized consistently with the categories we found to be critical defining this novel field (see Figure 3). Initially, it could be concluded that ICTs play a crucial role as enabler of Smart Cities. In this way, we identified three

Definitions	Context						Infrastructure							Processes						Approach						Factors			Goals								
References:	Urban area	Mean	Way	Result	Initiative	Urban environment	Physical infrastructure	ICT	Intelligent City	Human capital	Social Capital	Relational Capital	Communication infrastructure	Exploit information	Data collection	e-governance	Generate the knowledge-base	Delivering smart services	Triple helix	Creative strategy	Knowledge intensive strategy	Government-driven	Participatory governance	Interactive information	Performance metrics	High-tech and creative industries	Stakeholders	Environmental sustainability	React quickly to problems	Make better decisions	Add efficiencies	Improve city's operations	Sustainable economic growth	Social performances	Urban growth	High quality of life
[Kanter]							x							x	x				x						x			x	x	x	x					
[Harrison]	x																														x				
[Castineira]		x							x										x																
[Helal]			x					x																				x					x			
[Naphade]								x							x																	x				
[Lombardi]								x		x	x	x																x								
[Tranos]								x			x					x										x		x					x	x	x	
[Kourtit]				x																x	x							x				x	x	x		
[Leydedorff]								x	x								x	x	x																	
[Kuk]					x																	x														
[Caragliu]								x		x	x		x										x													x
[Schuurman]						x																	x	x			x									
Tot.	1	1	1	1	1	1	1	6	2	2	3	1	1	1	2	1	1	1	3	1	1	1	2	1	1	1	1	5	1	1	1	3	3	2	1	1
Tot. per Area	6						16							6					9						3			18								

Fig. 3. Smart City Definition Concept Matrix

fundamental milestones in building the technological background for Smart Cities, named the Spatial Intelligence of Cities [22]: Ambient Intelligence [23], Digital City [24], and the Intelligent City [25]. Respectively, they refer to the instrumentation, interconnection and intelligence steps presented in [2].

Furthermore, developing human resources and social capital are recognized, together with technology, as one of the enabler factors for Smart Cities by authors, e.g. [26]. According to literature, collaboration, participation, engagement, and partnerships are key words related to this field [5]. Hence, we need a collaboration model to actually establish technological and social components as enablers for Smart Cities. To support these approaches, researchers advocate the use of the "triple-helix" model which focuses in particular on relations between university, industry and government at an urban and regional scale [27]. Within this perspective, Living Labs methodologies [28] are stressed as being significant. Living Labs can be seen as a User-Centered Open Innovation Ecosystem [29] that aims at the integration of concurrent research and innovation processes within a "3P" (Public-Private-People) Partnership. Consistently, the balance between bottom-up and top-down strategies must be strengthened. To achieve these goals managerial interoperability across city's smart services, applications, and organizations is required [21]. At this point of development, we are in a good position to implement a Smart City strategy. Initially, we can state that the final goal of a Smart City is to provide services [5] in order to: improve city's inhabitants' quality of life [1], decrease city's carbon footprint [30], facilitate a sustainable economic growth [31], and increase or add efficiencies.

As a result of this process we identified all the key themes related to Smart Cities. At this stage we know what has been said, how many times and what a comprehensive definition should include. Thus, we define Smart City as *"an urban area that leverages its technological and social infrastructure implementing people-private-public partnerships supported by innovative governance in terms of policies, leadership and proper ongoing management principles, to enable smart information services, aiming at improving its critical capabilities"*. This definition encompasses all the critical aspects that arose from the literature currently available.

3 Choosing a Suitable Research Methodology

In the previous section we presented a SLR study on research to date within the topic of Smart Cities. Particularly, the concept definition matrix methodology allowed us to highlight what are considered the relevant concepts about conducting research in this emerging field. Furthermore, connecting to the introductory section of this paper, we highlighted with examples which is the current level of knowledge contribution of IS research projects in this field in relation to the level of knowledge maturity (see Figure 1). Hence, the aim of this paragraph is to find a suitable research methodology in order to enable the creation of prescriptive knowledge in terms of nascent Smart City design theory [32], considering all the relevant aspects arose from the SLR study. Particularly important for this scope is to consider the "Approach" category within both the concept definition matrixes previously introduced (see Figure 3 and [14]). Accordingly to literature, collaboration, participation, engagement, and partnerships

are key words related to this field [33] [5]. Hence, Smart City projects need a collaboration model to actually establish technological and social components as actual enablers for Smart Cities. To promote these approaches the largest portion of literature refers to a model called "triple-helix" which focuses in particular on relations between universities, industries and government at an urban and regional scale [27]. This perspective is critical to bridge the gap between short-term city development priorities (demand pull) and long-term technological research and experimentation (technology push) [16]. This approach has been widely demonstrated by several case study researches as successful (among others [9][11]). As a consequence, one of the critical success factors for Smart Cities research projects is considered to be the establishment of a strong "Public Private Partnership" in which local government, IT industries and universities are involved in a highly participatory approach to design and deliver innovative artifacts in this domain. The main aim is placed at leveraging the awareness of the mechanisms that characterize cities (from the government side), and the technological infrastructure associated with cities (from the IT company side), with the knowledge arising from extant academic theory (from the university side). In this landscape, in the early stage interaction between these three main actors involved, the problem that is wanted to be solved arises. Particularly, the local government highlights a specific issue regarding the specific city context. Researchers from academia import a theoretical standpoint, by rigorously analyzing the progresses of literature connected to the specific problem. In the case in which a solution is not available in literature, a research gap is identified, and as a consequence a solution needs to be designed. The outcome, i.e. the artifact, is meant as a thing that has, or can be transformed into, a material existence as an artificially made object or process [34]. It is clear that, if considering the dearth in existing theory only, Design Science Research (DSR) is a suitable research methodology. DSR is defined as a construction-oriented view of IS research in which the main focus is around designing and building innovative artifacts [13]. Moreover, *"the artifact should be relevant to the solution of an unsolved and important problem"*. Thus, *"the development of the artifact should be achieved from existing and proved theories and knowledge and should be a solution of a defined problem"* [35]. On the other hand, if we consider the challenge articulated by the local government, a specific organizational solution is needed. As a consequence the rationale for the choice of DSR as the proper research methodology becomes weaker. According to [36], researches using design science are initiated by the researcher interested in developing technological rules for a certain type of issue. In fact, in DSR the organizational intervention is considered to be secondary [37]. Particularly the DSR methodology sees as a first priority to gain complete awareness about the problem, then design the artifact, followed by its evaluation, tracing the so called "build and then evaluate" path. As a consequence, the organization plays an active role within the evaluation of an artifact that had been already designed. Notwithstanding, some key authors in the topic of DSR (e.g. [13]) believe that the organization can play a key role also in shaping the problem that is wanted to be solved. However, none of them sees a participatory design of the solution itself as one of the main features of the methodology. Hence, if we did consider only the local government side of the research motivation, we would probably choose Action Research

[38], which can be seen as the combination of theory and researchers' intervention to solve immediate organizational problems [39]. It is clear here that the organization is at the core of this research approach. However, once the organization-related solution is designed and evaluated, various forms of the organizational context are inscribed into the artifact [40]. As a consequence the contribution to existing knowledge might suffer due to the lack of insights for the generalization of the problem and solution instances.

Thus, concerning this methodological challenge related to IS research in the context of Smart Cities, we have to incorporate an "action component" within a DSR approach, in order to meet the needs of the local government and ensure an original contribution to existing knowledge. In literature an interesting (and consistent to this study) attempt to combine these two approaches was done in [41, pp.9], and it is drawn from [42]. The scheme that is considered here involves a naturalistic evaluation, as opposed to the artificial one, as the class of artifacts that are taken into account are much more involving conceptual elements rather than technical ones (see Figure 1, Level 2 of DSR Contribution Types). We see here that the organizational involvement (the action research component) happens only during the evaluation of the already developed artifact. In the case of Smart Cities there are two main differences and inconsistencies. In first place, the local government (and so the organization), has to be involved since the very first stage of the research. Secondly, the artifact has to be designed and developed in a highly participatory approach with the organization and the practitioners (from the IT company side). We can conclude that both DSR (in its original formulation) and Action Research are not suitable for IS research projects in the field of Smart Cities. However, we can conclude that IS research in Smart Cities needs to be DSR that recognizes that the artifact emerges from the interaction with the organizational context (i.e. local government).

A method that addresses these issues is Action Design Research (ADR), which is defined as a "*research method for generating prescriptive design knowledge through building and evaluating ensemble IT artifacts in an organizational setting"* [43]. Its particular contribution is linked to the implementation of design science research to solve an organizational-related problem defined as an instance of a class of problems, in which the evaluation is conducted in a highly participatory process [44]. The ADR cycle is based on four main research stages: (1) Problem Formulation, (2) Building Intervention and Evaluation, (3) Reflection and Learning, and (4) Formalization of Learning. The first step involves the definition of the problem that is required to be solved. Here, the problem has to be identified, articulated, and scoped. Particularly important at this stage, is to relate the organizational problem to a broader class of problems. This first stage of the methodology is drawn upon two principles: (1) *Practice Inspired Research* and (2) *Theory-Ingrained Artefact* [43]. Generally, research on Smart Cities has been initially motivated by "practical" (as opposed to theoretical) issues. Some examples are the widely mentioned urbanization trend, the growing responsibility of cities for the world carbon footprint, and the dramatic change in the demographic composition of the population [45], that are stressing cities' balances and infrastructures. More specifically, earlier in this section we have underlined how the issue arising from the local government is translated and related to a research gap in theory by the academic side of the research team. Hence, a wide range of academic

publications in IS literature in the context of Smart Cities demonstrates the effort that researchers are making to address these challenges with a theoretical perspectives, creating a range of original contributions to existing theories. The second stage of the ADR methodology is related to the process of building, intervention, and evaluation (BIE) of the artifact. Here again some principles are proposed in the ADR seminal article [43], that are (3) *Reciprocal Shaping,* (4) *Mutually Influential Roles*, and (5) *Authentic and Concurrent Evaluation*. After discovering initial theoretical contribution targets, the methodology also distinguishes between an IT-dominant-BIE (that is mainly focused on innovative technological design) and an organization-dominant-BIE (this format is related to the decision making processes within the organization). Both of these BIE types identify a highly participatory process, consistently with the calls for collaborative approaches made by several authors in the topic of Smart Cities (among others [46][47]). In detail, as concluded in [48], cities can be considered as densities in networks among at least these three relevant dynamics: that is, in the intellectual capital of universities, the industry of wealth creation, and their participation in the democratic government which forms the rule of law in civil society. The effects of these interactions can generate spaces within the dynamics of Smart Cities where knowledge production can be exploited. The evaluation phase is seen as a concurrent step, rather than a separate stage (principle 5). This particular approach allows identifying anticipated as well as unanticipated challenges related to the final solution. The importance of such an approach is ingrained in the concept of Living Lab [28], which it was demonstrated to be a successful way to design innovative artifacts in the context of Smart Cities by bringing together "*interdisciplinary experts to develop, deploy and test new technologies and strategies for design that respond to this changing world"* [49] (see also Special Issue on the Journal of Knowledge Economy [50]). The third step of ADR is crucial to ensure the contribution to knowledge of this research project, and it focuses on the reflection and learning process. This stage is drawn on the principle (6) *Guided Emergence*. In the context of IS research on Smart Cities, the final artifact is the result of the interplay that encompasses the relationship between the theories used and their application to the specific urban environment (including the local government, i.e. the organization) – related challenges [48]. Finally, the last stage proposed in [43] (i.e. Formalization of Learning) emphasizes once again the importance of having a (7) *Generalized Outcome* that can be further developed into general solution concepts for a class of field problems. The IS Smart City researcher is responsible of relating the specific city – solution to a significant contribution to theory by extracting the design pattern [51], understood as a generally reusable template solution to commonly re-occurring challenges (see [52]). The research outcome is then a theory-ingrained artifact, where theories allow the research team to both structure the organizational problem as an instance of a class of problems in literature, and guide the design [32]. The generalized outcome is achieved through the ongoing reflection and learning step, and the final formalization of learning one, by extracting the design principles [51] from the specific organizational-related solution. In this way, the organizational related problem can be solved without precluding the creation of an original contribution to existing knowledge.

Concluding, we found in ADR a relevant approach for providing systematic methodological guidance for current IS research conducted in the context of Smart Cities, and we demonstrated its suitability by relating its main principles to the key

notions arose from a SLR study. This statement will be further demonstrated within the next section, in which it will be provided an example of successful application of ADR in a Smart City research project regarding the development of a Sustainable Connected City Capability Maturity Framework (SCC-CMF) [52].

4 ADR in Smart Cities: The SCC CMF

The aim of this section is to describe a successful usage of ADR in a Smart City research project. It was conducted by a research team that included representatives from the academic field (National University of Ireland Maynooth and Dublin City University), in collaboration with Dublin City Council (DCC) and Intel Corporation, and was focused on the development of a Smart City maturity model (SCC CMF) [52]. In this paper we focus on outlining how the research activities that were implemented are consistently related to the 7 principles of ADR [43]. In other words, we focus on the methodology that was used, rather than on the content of the final artifact itself that was already widely described in [52]. A "quadruple-helix" approach [53] was adopted, where the awareness and the influence of the city authority as well as the technological experience and insights of Intel Corp., could be combined with rigorous research from the academic field (ADR, *Principle 4*). Moreover, the involvement of representatives from the city council and citizens of Dublin ensured the presence of the "people component" in the people-private-public partnerships collaboration model that was established, which is considered critical in any Smart City project [16]. Hence, a strong partnership between the stakeholders involved was officially established [56], and it was followed by initial meetings in which objectives, roles of each member of the research team, priorities and deadlines were clearly defined. Thus a long-term commitment to the project was achieved (ADR, *Principle 3*). The first motivation for this research project came from an organizational-related problem. The DCC senior management team highlighted the need they had for a comprehensive model in order to assess the current position of the city's Digital Master Plan. According to Dublin Lord Mayor Naoise O'Muiri', the master plan will be modelled with the idea of promoting initiatives to create an *"everywhere digitally connected and sustainable city, from home to workplace, from streetscape to public park and from healthcare to education"* [55]. At this stage we can conclude that the research was *Practice Inspired* (ADR, *Principle 1*). In the city's managers opinion a solution should be also able to define an improvement strategy in relation to the city's characteristics, priorities, and constraints. On the other side, a SLR to identify the related research opportunities and gaps within the existing literature base was conducted. Here, it was found that, despite the definition of many static indexes to assess the "smartness of cities", e.g. [5][54], there was still a lack of dynamic assessment models [9]. Thus, after a highly participatory preliminary analysis of the project between the parties involved, two initial research questions were formulated: (1) How can Smart Cities be assessed in relation to their current and future ability of delivering services

enabled by ICTs? (2) How can insights be given to city's managers to increase and optimize such capability?

It is clear here that the research addresses an organizational-related problem (DCC) defined as an instance of a class of problems identified through the SLR study. After discovering initial theoretical contribution targets, the research team had to select and customize the BIE cycle. Within the continuum between an IT-dominant-BIE and an organization-dominant-BIE, the project was much closer to the second option, as the artifact was designed with organization's participants input and ideas (ADR, *Principle 3*). Within the BIE cycle, the first version of the artifact was achieved as a part of a PhD program, by applying a theoretical lens to the dearth of existing theory, and by the usage of several research techniques (e.g. Grounded Theory [57], 8-steps SLR [19]), as described in [58] (ADR, *Principle 2*). The possibility of leveraging this first stage of the model by embedding the experience and competences from both DCC and Intel resulted in a significant change and improvement of the artifact, again consistently with *Principle 3* of ADR. Furthermore, as documented in [52], an ongoing evaluation of the artifact was achieved by involving Dublin City stakeholders since the first version of the solution was designed. Particularly, a city workshop was conducted involving city stakeholder representatives from those areas of the city in which Smart City ICT-related solutions are expected to be implemented. Among other activities that were implemented (e.g. individual and group-based assessment of the current level of maturity of Dublin City), the stakeholders had a further group discussion on potential improvements that can be done within the SCC CMF. Here they highlighted their ideas about future initiatives, potential benefits, as well as the challenges and obstacles that have to be overcome to allow their full implementation. As a consequence, the BIE cycle identifies a highly participatory process with the evaluation phase that can be seen as a concurrent step, rather than a separate stage (ADR, *Principle 5*). As a summary, the solution evolved since its first version through its usage by end users (i.e. responsible for the Dublin Digital Master Plan), and the inputs collected from stakeholders within the city (ADR, *Principle 6*). Concluding, by extracting the design pattern [52], the research team ensured that the outcome achieved with the design of the SCC CMF goes beyond the specific city solution (i.e. Dublin) (ADR, *Principle 7*). Despite filling the research gap previously identified, this research project gave constructive insights to the Smart City IS research community on how to systematically standardize this complex field. Furthermore, the SCC CMF is now being used to facilitate *"quantitative benchmarking across cities"* and as a "*standalone city assessment instrument"* [52]. In addition, the presence of researchers from academia facilitated this process, as their main interest was to keep the process rigorous and systematic.

Concluding, in this section an example of successful application of ADR in a Smart City project was described. Its consistency with [43]'s methodology was demonstrated by relating the research activities that were widely described in [52] to the 7 principles of ADR. These relationships will be summarized in the concluding section of this paper (see Table 1).

Table 1. ADR Principles in IS Smart City Research

ADR Principles [43]	IS Smart City research	SCC CMF [52]
Practice-Inspired Research	Smart City research activities are problem-inspired, from mega trends (e.g. urbanization) that are stressing cities' balances and infrastructures [2].	The research project had as a starting point the issues articulated by the senior management team within DCC, i.e. need for an artifact to inform the strategy to become a Smart City.
Theory-Ingrained Artifact	The practical problem is related to a research gap in literature, and IS theories systematically drive the activities involved in the design of the artifact.	A mix of theories and research techniques was used for systematically drive the research activities (e.g. Grounded Theory [57], Maturity Models [59], 8-steps SLR [19]).
Reciprocal Shaping	The effects of the interactions-between local government, IT industry, and academia-generate spaces within the dynamics of cities where knowledge production can be exploited [48].	The involvement since the beginning of the project of DCC (i.e. the organizational setting) ensured a participatory approach in designing the SCC CMF, which was then inevitably influenced by the specific context.
Mutually influential roles	The IT artifact is developed in a Triple-Helix environment [27], where IS theories (academic side) inform the practical knowledge related to the city (government side) and its technological landscape (IT industry side), and vice versa.	The final artifact is the result of the leverage of the awareness of the mechanisms that characterize cities (from Dublin City Council), and the technological infrastructure associated with cities (from Intel Corp.), with the knowledge arising from extant academic theory.
Authentic and Concurrent Evaluation	The importance of such an approach is ingrained in the concept of Living Lab [28], which was demonstrated to be a successful way to design innovative artifacts in the context of Smart Cities [50].	An ongoing evaluation of the artifact was achieved by involving Dublin City stakeholders since the first version of the artifact was designed. Additionally, end users (i.e. responsible for the Dublin Digital Master Plan) actively participated in the design of the artifact.
Guided Emergence	The artifact is the result of the interplay that encompasses the relations between the theories used and their application to the specific urban– related challenges [48].	The solution evolved since its first version through its usage by end users (i.e. responsible for the Dublin Digital Master Plan), and the inputs collected from stakeholders within the city.
Generalized Outcomes	The IS researcher is responsible of relating the specific city – solution to a significant contribution to theory by extracting the design pattern [51].	The SCC CMF goes beyond the specific city solution. It is currently being used to facilitate *"quantitative benchmarking across cities"* and as a "*standalone city assessment instrument"* [52]

5 Conclusions

This paper demonstrates the suitability of Action Design Research [43] to systematically focus on the complex research challenge associated with the topic of Smart Cities. As a summary we propose Table 1, in which the relations between the 7 principles of ADR with both general IS research on Smart Cities and the particular case described in the previous section (i.e. the SCC CMF), are outlined.

To support this statement, we firstly used [12]'s framework to describe the progresses to date of IS research in Smart Cities in terms of current research contribution targets in relation to the level of maturity of the knowledge in this field. Based on this, we conducted a SLR in order to investigate the key concepts upon which IS research on Smart Cities is currently grounded. The systematic identification of these concepts allowed us to both outline the methodological challenges that Smart City research projects are currently facing, and to demonstrate how ADR can be a suitable approach in this highly collaborative and practice inspired research landscape. Particularly, we showed how the main concepts arising from the SLR study are consistent with the 7 fundamental principles of ADR. In addition, we provided an example of successful application of ADR in this research domain, by focusing on the research activities implemented in the design of the SCC CMF [52].

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