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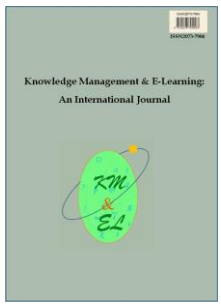

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Design smart city apps using activity theory

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Abstract: In this paper we describe an innovative approach to the design process of Smart City interventions. We tested it with participants enrolled in the Master's Degree program in "Innovators in enterprise and public administration": the objective of the Master was to stimulate the acquisition of technical and methodological skills useful in designing and implementing specific Smart City actions. During the "project work" phase, participants learned about a design method named SAM – Smart City Model - based on the Cultural Historical Activity Theory (CHAT). We present an overview of design criteria for Smart City projects, the description of the theoretical framework of Activity Theory, and our proposal of the SAM design model. We also present some examples of student's "projects" and a more extensive description of one case study about the full design process of an App planned using SAM, for "smart health" vaccine management and monitoring services. The App was later published and made available to the citizens and was successful in attracting thousands of users. All the participants considered the model very useful in particular because it made possible to understand the interaction and solve contradictions between different stakeholders and systems involved.

Keywords: Smart cities; Activity theory; Knowledge management

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Dr. Cinzia Ferranti is a post-doc researcher at Department of Philosophy, Sociology, Education and Apply Psychology at University of Padova. She has been involved in several researches in the areas of education technology to sustain professional communities, to design courses in higher education and to manage teacher training programmes.

1. Introduction

In 2015 we started a Master's program entitled "Cloud Learning – Innovators in Enterprise and Public Administration" at the FISPPA Department of the University of Padova. Many of the participants came from various municipalities, local health authorities or public entities of the Region. In agreement with their respective authoritative administration, they enrolled in the master's program with the aim to acquire technical and methodological skills useful for designing and implementing specific Smart City actions. In fact, several times during public meetings held on the subject with many local stakeholders including ASL (Health), ANCI (Association of Italian Municipalities) and the Veneto Region, the need to train experts that are able to deal with public service issues, particularly health care, tourism and administration was highlighted. The European Community has moreover long identified as one of the most important goals of EU 2020, the issue of technological innovation aimed at developing and improving the quality of life of citizens in the most heavily urbanized areas (European Commission, 2012). According to the EU definition, in a "smart city" traditional services are made more efficient with the use of digital technologies for the benefit of its inhabitants: smart and sustainable cities in fact, aim to better use technologies to manage city services and infrastructures. As a consequence, the master wanted to meet these training needs, focusing especially on the planning stage of actions under the objectives of Smart Cities of Europe 2020.

2. The need for a systemic design for smart cities

The report "Mapping smart cities in the EU" (Manville et al., 2014), included around 500 European cities that had over 100,000 inhabitants engaged in Smart City projects it is interesting to note that two thirds of the projects were still in the advanced planning or pilot testing stage; a clear indication of caution when actually implementing them in the field. Italy, along with Spain is among those European countries that have the most smart-city projects in: Venice, Milan, Genoa, Turin, Trento, Bologna and Naples. Despite the interest in the topic, a discussion on reliable design models and methods is difficult to find (Letaifa, 2015) (Mattoni, Gugliermetti, & Bisegna, 2015). An overview of models shows different Smart Cities concepts. Yet there are 6 dimensions that are part of most models: people, government, economy, mobility, environment and living (Anthopoulos, Janssen, & Weerakkody, 2015) but many different approaches in the design of the interventions are used. The ones that seemed to give a better guarantee of success generally respected the criteria of:

1) clear objectives,
2) specific and concrete results,
3) broad support and engagement of citizens and governance at a social and political level (Berntzen & Johannessen, 2016).

With respect to the third point mentioned, in fact, citizens should not only be the targets of smart city projects, using the "ready-to-consume" outcome: but they should also be an important element of the smart city architecture and their consideration is important for the smart city project to be successfully implemented (André, 2015). User-centric and bottom-up initiatives through active involvement (Sankar & Cumbie, 2015) are therefore important to develop smart empowered citizens because above all, a Smart City is a Smart community of people (Manville et al., 2014, p.86). In addition, a *participative governance* (Schaffers et al., 2011; Lee, Hancock, & Hu, 2014) is essential

in order to clearly define the technological, organizational, regulatory and financial factors that may be involved and that need to be taken into account during the various design stages. As much as the focus is centred on technology, it's important that an interdisciplinary systemic perspective is adopted that is able to integrate all the other social, economic and political elements (Letaifa, 2015).

Trying to evaluate Smart Cities interventions is not easy: an interesting European Project "CityKeys Project" started in 2015 (www.citykeys-project.eu/) tried to develop and validate a performance evaluation framework (Fig. 1) to define key performance indicators in order to support the smart city development. By using a set of "smart project" indicators a city can assess the results of any project in various aspects of city life (economic, social, energy, environment, etc.) and in terms of input/output, process, impact and outcome indicators. For example, an "input indicator" can be the project costs; a "process indicator" can be the number of ways in which citizens can communicate with the municipality (phone, mail, social network, etc.) and an "outcome indicator" can be the spread and the use of a Smart mobility App. Analysis of the success factors across cases show that: 1) Political leadership and 2) the adoption of an integrated, holistic, approach to smart city development stand out as critical factors (Ojo, Curry, & Janowski, 2014).

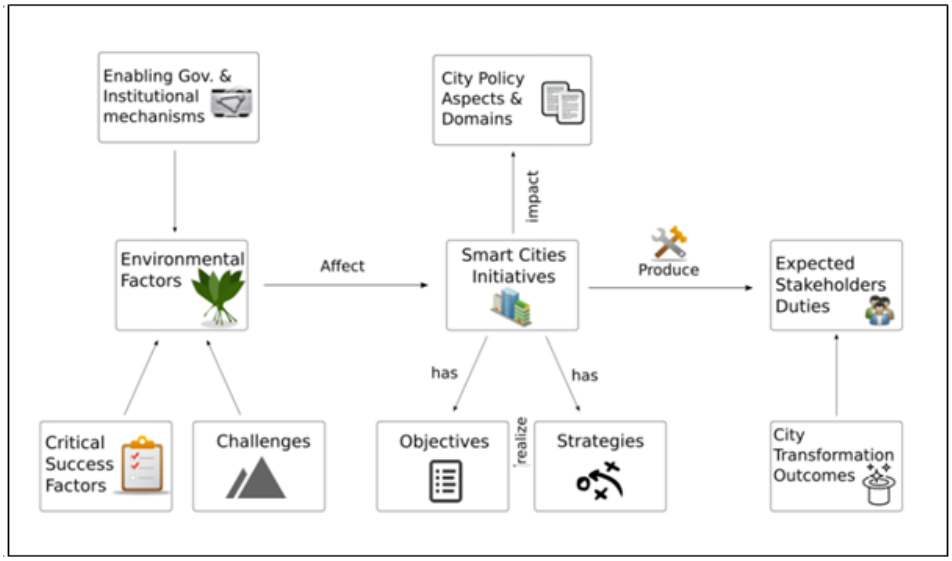

Fig. 1. An example of conceptual model for smart city initiatives. Adapted from Ojo, Curry, and Janowski (2014).

It is also difficult to find a clear and general framework to plan Smart City interventions: many authors use complex frameworks and models often based heavily on a specific topic or dimension (technology, urban planning, business, mobility and people, etc.) (Zygiaris, 2013; Nam & Pardo, 2011; Bork et al., 2015) and micro-macro levels (Letaifa, 2015). One example of a conceptual model for Smart City Initiatives is the Ojo, Curry, and Janowski, (2014) model (Fig. 1): this is one of the simplest, but it does not consider other meaningful relationships between all the stakeholders, technologies and processes involved.

3. The activity theory framework for the design of smart city interventions

A more flexible, modular framework (Fig. 2) able to effectively represent the many and complex relationships and processes involved in the Smart City project, is the "Cultural Historical Activity Theory" (CHAT) (Engeström, 1987), in particular for its interpretation of the role of technologies seen as mediators of the activities of individuals acting in a coordinated way in order to achieve a specific goal (Kaptelinin & Nardi, 2006). According to this interpretation, one may in fact describe the activities of a complex socio-technical system, as the creation of a Smart City intervention analyzing the interrelationships of six elements that contribute to the realization of an "expected Outcome":

- Subject(s) - actors engaged in the activities;
- Object - the objective of the activity system;
- Community - social context;
- Tools - the technological artifacts (instruments) used by actors in the system;
- Division of labor - the division of activities among actors in the system;
- Rules-conventions, guidelines and rules regulating activities in the system;

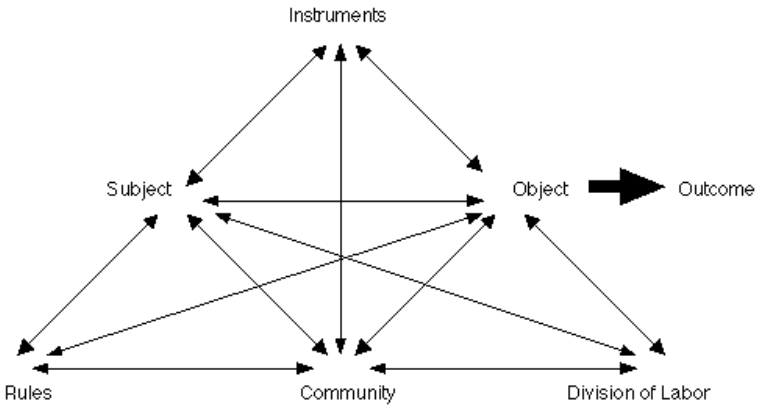

Fig. 2. An explanatory diagram highlighting the interrelationships of the elements of a business system according to the cultural historical activity theory (CHAT). Adapted from Engeström (1987).

Among the various elements, some critical issues often emerge, that in the Activity Theory are defined as "contradictions" (Engeström, 2001a). The contradictions between two elements of the triangle are the starting point for the recognition of the principal stresses in a system, but also to show a possible direction for the evolution of the activity system itself. For example, the contradiction between the rules and the subject can lead to review some laws or change the behaviour of the subjects (for example the case VaccinActions, where the change of a regional law conducted to modify the perception of prevention policy and particularly of the process of vaccination).

It's 'important to note that the contradictions are intended not as occasional problems that may or may not influence the Subject, but they represent a real structural component of the system that affects all the elements. Engeström also defines multiple

levels of contradictions, starting from the internal ones (for example, between the subject and the community or between the Community and the Rules) until you reach the outer ones that occur between different activity systems.

3.1. The use of Activity Theory in the participants' projects: The development of the app as an outcome and tool context

Participants in our Master's program attended a short workshop on Activity Theory, after which they were invited to design their proposals for Smart City interventions using this particular framework. Most of the participants were experienced professionals in their field with a good knowledge of their organizational context, so it was not too difficult to identify concrete elements at play in the activities System, elements that each participant accounted for in his project. The research phase, where they analyzed critical relationships among themselves and recognized the potential "contradictions" emerging in the System was more difficult, but very interesting. This historical-cultural analysis process of the various organizations has led to many participants in the Masters to develop a deep understanding of how each organizational context in which they belong to can evolve positively, and in this way solving one or more contradictions present thanks to the innovations introduced in the project.

Use of the Activity Theory, however, has required us to pay special attention to the items "Outcome" and "Tools": most of the projects in fact wanted to have as the "Outcome", an App to install on a smartphone or tablet to be used by individuals, but the analysis has also highlighted the need to consider this App as part of two Activities Systems that take on two different roles. In the first role, the App is conceived as the "Outcome" for the design System and in the second role instead intended as a "Tool" of another Activity System the citizens' one, which interacts with the first one. The broadening of the design perspective that involves two Systems, one of *production* and one of *use*, then drove us to elaborate an ad hoc model, useful for the participants in order to improve their understanding and the design of Smart City interventions: the SAM model.

3.2. The SAM - "Smart City Model" and the interaction among different activity systems

We therefore developed the SAM project model - Smart Activity Model, which enabled us to transform the learning experience of the Masters into a real organizational project, which was set out through a project-based learning approach (Krajcik & Blumenfeld, 2006; Bell, 2010). As we have seen, the first step required the reconstruction of the current Activity System from which one could begin the plan design. Subsequently the relationship between two systems in which the key elements are the design and the use of application software that are able to resolve some of the contradictions emerging from the analysis of the Activity System and can help it evolve effectively was outlined. All the projects proposed have had to review the information systems related to their Activity System; in some cases, the activity itself was related to information services for the management of municipal services, education or health.

An important step was also the detection of secondary contradictions between two components of the System or tertiary ones between components of two different, but neighbouring, Systems (Engeström, 1987). The model we proposed, which is directly derived from the research of Engeström, is therefore based on the union of two Activity

Systems: the production of apps and the use of the apps (Engeström, 2001a; 2001b). Keeping these two Systems closely linked is critical in order to explain some elements that enable us to proceed with the delineation and the implementation of the entire project. The first stage of the design is thus based on the identification of the two Activity Systems structure where the key element is the production of a tool that will be used by citizens, i.e. by the users of the service. Some examples of an interaction between the production system and the use system are highlighted in the next pages as a list of projects based on the SAM model.

Designing an App thus becomes a systemic operation, unless it is considered solely on the basis of the technical aspects of production, and all the basic elements of Activity are taken into account. Participants in the Masters had to bring out the underlying rules (different normative levels, different cultural rules that affect the attitudes and the practices, the target community needs, especially in view of how the App is used, and inside of which there is the single citizen who benefits from the designed information systems).

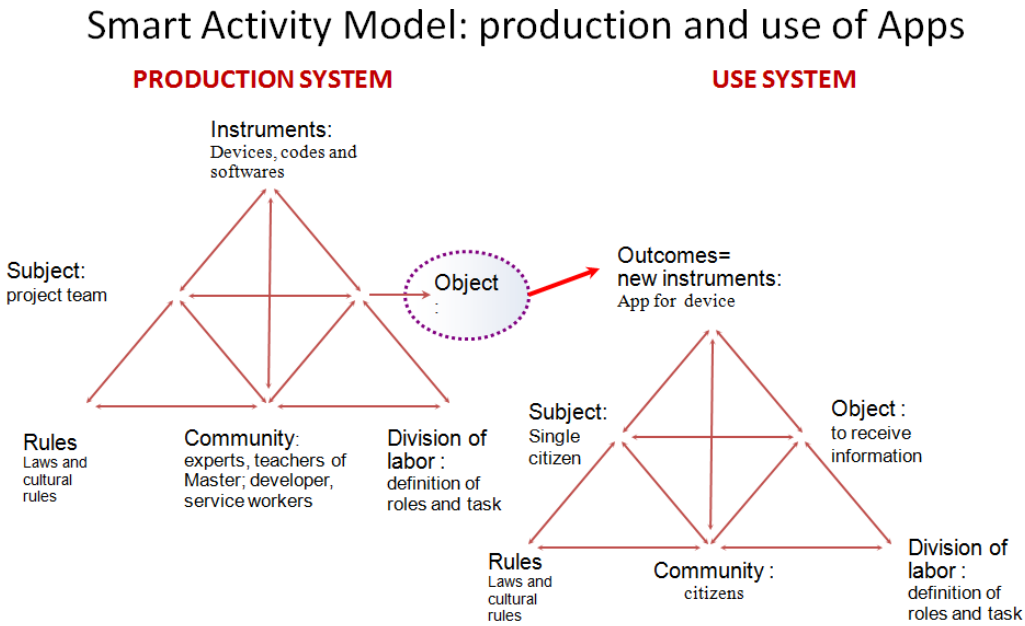

Fig. 3. SAM - Integrating the production and the use systems to innovate the informative relationship with citizens

After the representational rebuilding of the two systems (Fig. 3), in order to complete the design, we proposed to follow some steps called SAM DESIGN STEPS (making explicit the information needs for the app design) which include:

- The emergence of the main CONTRADICTIONS - identification of the most important contradictions in order to design an information system that meets the needs of the evolution of the System (Van Amstel, 2015);
- The creation of KEY QUESTIONS - leading questions that help to identify key information elements (Balakrishna, 2012) used for shared planning (their nature, form, value and timing, ...)

- The use of a DOCUMENT MODEL for the descriptive part of the project document, namely a format of logical design sequences.

The SAM model has much strength, but also some limitations. It is suitable for identifying the main directions of evolution of the system and it is particularly profitable for the macro-design processes. Nevertheless, it does not appear to be the most appropriate instrument to manage the micro-planning level of the App and the specific information flow. For these processes, the project team should make use of other design tools. Especially for App development aspects, it should make use of specialized and technical knowledge, which also takes into account the vision of any participatory planning systems that enables to respond to the needs of citizens.

4. Projects based on the SAM model

The projects based on the SAM model are consistent with a vision of both restructuring of citizens' services and of an evolution of the urban idea which is considered smart because it simultaneously simplifies and innovates processes like communication, the use of services by citizens be they a general user, a patient, a tourist or a student. The project work experiences of the participants are clear examples of how the SAM design model can help one to focus on the fundamental directions for thinking in an evolutionary manner about the services of one's own city (seen from inside a local authority, a municipality, a local health authority, or a public-school system). Among the different projects presented, those related to the App designed with a smart cities approach, are:

1) *Training to Applift*, proposed as a service of the City of Venice in which internal training requirements meet the activities of the P3@ centers that are public access points and offer free internet (about 300 in the entire Veneto Region). They provide space for the use of computers connected to the Internet, but also provide access to a wireless network that can be accessed with the devices of citizens and many other services such as online assistance for municipal services, education and health care. The project work was based on the design of an application to collect the needs and publish the items that relate to the digital education of citizens, taking advantage of the network of Internet Centers P3@ of the City of Venice;
2) *The municipality in your home*, a project that has managed to incorporate emerging needs with the model of the Theory of activity and the design of citizens services that are faster, smarter and more convenient. This project responds to the needs of administrative simplification, in which the main objective was to try to enable individuals to obtain some type of anagraphical certification, sometimes anticipating the very questions of the citizen. After an initial pilot test and the monitoring of the results (evaluation of the time and cost), it is expected that the electronic service for the simplification of all administrative procedures will be perfected.
3) *From W.E.B 3.0 to Health 3.0*, is a very complex project that put forth intelligent health solutions based on a new approach to communication. In fact, the project integrated several innovative initiatives from the Health authority in Padova, reaching the full potential that can be found in the semantic web or Web 3.0, towards a model of healthcare that is closer to the patient or provides better health "with" the patient.

4) *Health in Holidays* is a project that concerns *health* smart processes. It was based on the development of a mobile app to assist tourists, residents and people on the move in the Veneto region in the prompt identification of the most suitable health care facility available in case of an emergency (first aid and emergency medical services). The App combines a variety of information: the availability and distance of the emergency services, the nature of the symptoms, the target, opening hours and georeferencing. All information services are provided in different languages and the language selection is carried out automatically according to the mobile device settings. The project originated as a result of some contradictions that came to light about the existing regional information system and the detection of a lack of an easily accessible tool to locate emergency services, especially for people who are not familiar with the territory. The idea was proposed by a group of participants in the Master's program consisting of the mayor of a tourist town of Lake Garda and two information systems experts that work in the Health authority of a town in the province of Venice, which also targets its services to the tourists who come to the sea, in the Venetian coast.

4.1. VaccinActions case: App and innovation of the regional information system SAM model

Another project developed with the SAM model was called "VaccinAzioni Veneto - Development of an App for the integrated management of Immunizations". Also, this project was about "smart health": this confirms that healthcare in smart cities frameworks is perceived as critical area of intervention (Saade, Vahidov, Tsoukas, & Tsoukas, 2015). We chose to describe it more extensively, as a case study, to show in more detail how the SAM design model was set out in this concrete example. Again, in this case there was the need to provide a range of information which together makes up a smart service for the management of vaccination throughout the Veneto Region. Analysis of System contradictions led to the identification of the needs associated with the possible development paths for the same system, which are provided below:

- *Removal of vaccination requirement*. After the year 2007 (Regional Law no. 23/2007), the Veneto Region, no longer requires that children and adolescents be immunized. This choice has resulted in greater and more widespread informative action to maintain the high vaccine coverage levels reached previously.
- *The perception of risk associated with vaccination*. Communication initiatives at the national level and information disseminated by the media have influenced the behavior of citizens. Many consider there to be a very high risk associated with vaccination, without analyzing the real risk of not getting vaccinated. For example, while there remains a critical mass of individuals that are already vaccinated, they create a barrier against the diffusion of the disease, and this barrier would disappear once a critical mass of individuals refuse to get vaccinated: the result would mean that diseases that were once eradicated could come back.
- *Changes in the regional information system due to the presence of a single regional web based software*. It enables among many features to manage invitations for immunization drawing on regional or customized calendars on the basis of the social-health situation of the individual citizen

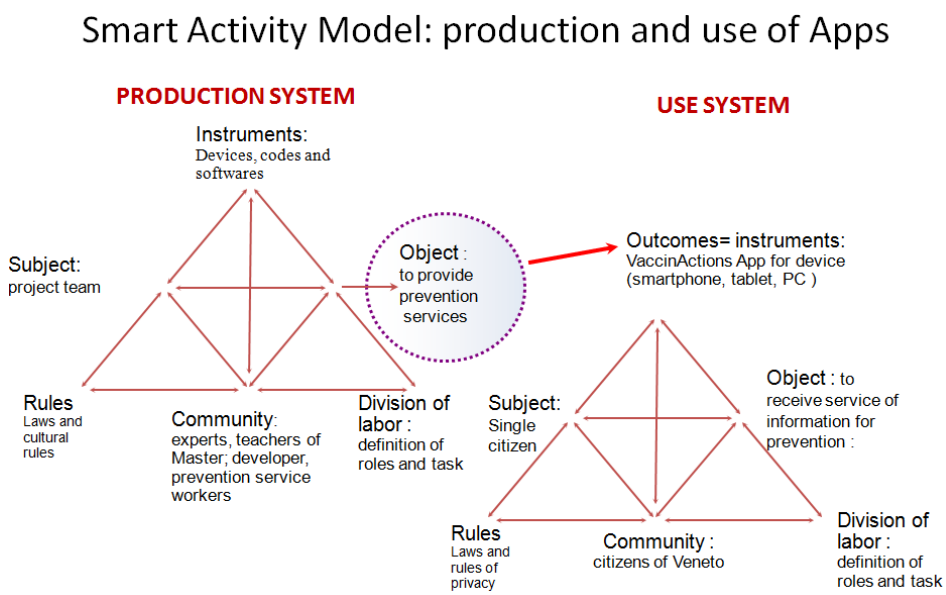

Fig. 4. VaccinActions - SAM model applied to an App for informative health prevention

Starting from the above considerations, the main focus of *Project Work* (the final project of the participants) into the Master "Cloud Learning" was the delineation of the production system of the App through the SAM model (Fig. 4). This has engaged, but also changed some organizational practices related to the existing business system. We now go on to describe the role of the elements at play.

The *subject*, is the sum of people involved in the project team, that since their enrollment in the Master's program are called upon to work together to design the App (two participants, the first one is an expert in Regional Information Services and the second one is an administrative collaborator of the Regional Health Planning Section; in addition to them, there was a group of regional workers: analysts and app developers).

The *object* is the goal or the direction of activities that, although in this case is linked to the design of an app, is always connected with the aim of the organization, that is, providing services for infectious disease prevention through vaccination.

The *outcome*, the entirety of the outcome of the activity, in this case, the concrete creation of the app that will be used in the operating system as a new tool.

The *tool* that is, the resources and the means to achieve the goal, is represented by the code, the software and the devices used to program the App.

The *rules* are the norms which set the framework and define the interactions within the activity. In this case, the law that removes the vaccination requirement, the law on protecting the privacy of citizens and the provisions about the development of electronic health records.

The *community* is the whole sum of protagonists which refer to the construction of the new App activities therefore the set of experts, trainers of the Master program, the health-care community and the App developers.

The *division of labour* is the specific configuration and combination of roles and responsibilities of the people involved in the entire innovation of the Regional Information System for vaccinations.

Even in the operating system, one can identify the different actors and key elements of the activity. Of particular relevance:

- The *individual* citizen that uses the App, and receives general and personalized information on vaccinations that he and his family can get;
- The *tool* or the App with its specific functions and interactions that enables the user;
- The *objective*, namely to receive the information needed for health prevention;
- The *outcome* or the possible outcomes of the use of the App (that should be checked and that tabulate numerically how many use it, whether and how to maintain the percentage level of vaccination, that are also linked to detectable epidemiological data).

A major change in the modality the relationship with the citizen is the fact that the App forges a direct and dynamic relationship between the community and the organization of the immunization system, whereas before this relationship was indirect and impersonal. The work of reconstruction of an Activities System related to elements so important as the community is essential, but it is not enough to specifically design an app that meets the needs of the entire System and the needs of individuals (single citizen) who will use it. It was in fact important later, to clearly define the information needs so as to imagine which app features would be most appropriate to respond to the stresses placed on the Activities System from which we started. Two main informative categories emerged from this approach in the use of the App: one of *public information*, which does not require authentication processes (diseases that can be contracted if we do not get vaccinated, list of available vaccinations, news & services) and one of *private information* (personalized news, personalized schedule, specific location for vaccinations, appointment calendar, and vaccinations that have been carried out).

The main feature of the latter option is that it is highly customized and provides specific data that depends on the registered users profile and enables minors to get their parents to access the information and manage the scheduled appointments.

5. Participants perceptions about the SAM model

To test the usefulness of the model in the projects design we analyzed the perceptions of 20 participants (M=9, F=11) at the end of the Masters activities, through a short questionnaire. The results were encouraging: more than 90% of the participants considered it "useful" or "very useful" to use the model in the initial design stage (Fig. 5) compared to a conventional design they used in past.

It's interesting to analyze the reasons for these findings (Table 1): the majority of participants see the model as a concept tool that is capable of representing effectively and comprehensively all the elements and their interactions (72%), especially between different activity systems (54.5%) (for example, Public institutions and citizens). Also, to note is the perception of the model as a tool that facilitates communication of the project to politicians or administrators (36.4%). Finally, more than 80% of the participants believe they can use the SAM model in the future for designing other Smart City interventions.

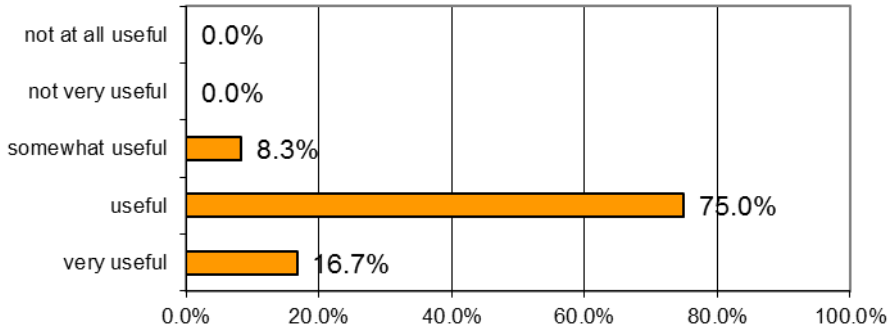

Fig. 5. The perceived usefulness of the SAM model

Table 1
Perceived usefulness of the SAM model (more than one answer)

It has effectively represented all the elements and their interactions.	72.7%
It made it possible to understand the interaction between the two different systems involved (e.g.: my institution and the citizen).	54.5%
I have been able to easily explain my project to others or to the administrators and / or politicians.	36.4%
I have been able to clearly define the problem that the app had to deal with.	18.2%

6. Conclusion

Using the Activity Theory (AT) as a project/reflection tool proved to be particularly effective, both as a reference framework for the design of specific Smart City interventions and as a training tool capable of creating a bridge between formal learning conveyed in academia and real-world contexts. The participants highly appreciated the peculiar characteristic of the AT to foster a systemic vision which clearly represents the various elements involved and identifies technologies as important mediators of the processes.

In particular, the SAM model has enabled participants to consider the development of technologies, such as the App, not only as a mere product, but also as part of multiple different systems of activities that can adequately represent the requests and the points of view of all the social stakeholders involved in the production and in their use. This goal, as we have seen, is typical of a quality Smart City design and of a genuinely participatory governance. However, the promising results of this experience need to be tested in more varied smart city design contexts, to confirm the broad usefulness of the SAM model.

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