Journal of Universal Computer Science, vol. 25, no. 8 (2019), 1018-1038
submitted: 26/12/18, accepted: 9/7/19, appeared: 28/8/19 © J.UCS

A Model for Resource Management in Smart Cities Based on Crowdsourcing and Gamification

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Abstract: Resources of a city are urban assets such as hospitals and pharmacies (health facilities) or accessible ramps and adapted toilets (accessibility resources). This paper addresses the problem of resource management for smart cities combining crowdsourcing with gamification, and proposes a model called CORE-MM. This model allows the use of crowdsourcing techniques so that the management of cities resources is done by the citizens, without having to rely on an organization or public administration. To encourage participation in this resource management, this model also uses techniques of gamification. CORE-MM proposes the use of crowdsourcing integrated with gamification to manage the resources of a smart city, with two interdependent objectives: to motivate the use of the system by the users, and to encourage their participation in the sharing and management of information. The scientific contribution of this work is that CORE-MM treats the resource management considering a generic resources approach for smart cities. A prototype of CORE-MM was offered to volunteers and a questionnaire was developed to collect data and to evaluate the model, its performance and relevance. Results with volunteers indicated good perceived ease of use and good perceived utility. From the affirmations of the questionnaire that the 10 volunteers that tested the CORE-MM prototype had to answer, 91.67% agreed on the ease of use of the system and 8.33% manifested indifference in their responses. Regarding the utility of the system, 99.17% agreed and only 0.83% were indifferent. These results point to positive perspectives regarding the use of the application in possible situations and real locations.

Keywords: Crowdsourcing, Gamification, Smart Cities, Ubiquitous Computing, Mobile Computing, Resource Management, Model, Accessibility, Health, Care Resources.
Categories: H.3.2, H.3.3, H.3.4, H.3.5, H.4, M.0, M.3, M.5, M.7

1 Introduction

Smart cities are a relevant topic in terms of improving people's living conditions, so much that governments and private companies are investing significant amounts of money each year to research, develop and implement this concept. According to Washburn et al. [2010], a smart city is the use of smart computing technologies to make the critical infrastructure components and services of a city (e.g., city

administration, education, healthcare, public safety, real estate, transportation, and utilities) more intelligent, interconnected, and efficient.

For several types of needs and objectives, such as accessibility [Barbosa et al., 2018] [Telles et al., 2016] and health [Vianna et al., 2017] [Pittoli et al., 2018] among others, there is a large number of people who need simple and quick ways to find the resources they need. And digital systems can be designed to help these people find such resources.

Supporting people who are looking for these types of resources, cited in the examples above, can be a challenging task, as the problem is how to map and keep up-to-date such resources for an entire city. But a resolution to this problem may be possible, provided that a model aimed at this is proposed and evaluated. The examples mentioned above were in the areas of accessibility and health, but the mentioned solution may include different types of resources from different areas existing in a city, such as tourism resources (parks, theatres, places of visitation and more), utility resources (such as bus stops and or bus locations, trains), among others.

Crowdsourcing, or collective intelligence, according to Brabham [2010], is a term coined by Howe [2006] in an edition of the 2006 Wired Magazine and in his subsequent book on the subject [Howe, 2009], and is basically an open call for anyone interested to contribute a task, rather than delegating it to just one skilled person, thus gaining time, productivity, and lowering costs for a task that could be much more time-consuming or costly to perform.

Gamification [Seaborn et al., 2015] [Dias et al., 2018] [Deterding, 2012] is the application of game design mechanics and techniques based on rewards and incentives for players to perform tasks (visiting a website, using a product, and more) in non-gaming contexts, applications and environments. The purpose of using gamification is to create stimuli for users, in order to motivate the target audience to engage in these tasks more frequently and deeply.

From all these concepts, gamification can then be combined with crowdsourcing to solve the problem of how to map and maintain up-to-date resources of an entire city. Gamification can be used by a system for smart cities to promote and stimulate crowdsourcing, and demonstrate that such behaviour – of promotion and stimulation - described by O'Donovan et al. [2013], actually occurs when gamification is well implemented.

This paper presents the results of a master dissertation [Orrego, 2017] that addressed the problem of resource management for smart cities combining crowdsourcing and gamification and proposing a model called CORE-MM. This model allows the use of crowdsourcing techniques so that the management of cities resources is done by the citizens, without having to rely on an organization or public administration. CORE-MM proposes the use of crowdsourcing integrated with gamification to manage the resources of a smart city, with two interdependent objectives: to motivate the use of the system by the users, and to encourage their participation in the sharing and management of information. None related work considered the resource management of cities through a generic approach, which means that neither is generic in relation to the resources and areas of application. Therefore, the scientific contribution of CORE-MM is the generic resource management for cities.

This paper is organized as follows. Section 2 presents related work. Section 3 discusses the model, its architecture and data types. Section 4 describes the evaluation methodology, the prototype used for evaluation, the evaluation by voluntary users, the questionnaire applied and the results. Finally, section 5 concludes this work.

2 Related Works

Related works were selected from researches in digital libraries in the areas of this work, such as IEEE Xplore Digital Library, ACM Digital Library, Springer International Publishing AG, CAPES journals bases, SciELO and Google Scholar. These searches were based on the search for works that have the keywords: smart cities, crowdsourcing, crowdsourcing for smart cities, gamification, gamification for smart cities, serious games for smart cities, ubiquitous computing for smart cities and variations of these, as well as combinations between them. After the searches, the works were submitted to a comparative based on criteria that include functionalities and technologies able to manage systems, users and enable the management of resources of a smart city, using crowdsourcing and gamification.

Criteria for comparing related work can be listed, and thus contributions can be identified in the areas of gamification, crowdsourcing and smart cities. The comparison criteria are as follows: (1) whether the work uses crowdsourcing; (2) whether the work uses gamification; (3) whether the work combines crowdsourcing and gamification; (4) whether the work mentions smart cities; (5) whether the work is focused on resource management for cities; (6) the area in which the work is applied (or the types of resources on which the work is focused); (7) the target audience of these resources; (8) and the target audience for resource management, that is, who manages resources in these works.

Tables 1 and 2 summarize the comparison from these criteria. The works were divided into two tables for better visualization, however the comparison criteria are the same. In these tables the acronym "PwDs" stands for "People with Disabilities", the acronym "CnCDs" stands for "Chronic Noncommunicable Diseases" and the abbreviation "Admins" stands for "Administrators".

It is worth noting that although these related works use resource management, information about resources can be updated and shared by users, but new resources cannot be added directly by them, needing to be accepted or confirmed by administrators. In addition, in the works that used crowdsourcing, gamification could have been used to motivate the participation of the users. And also, in works that use gamification, crowdsourcing could be used to streamline resource mapping, increase mapping reach, and even apply the models in different cities.

Ubibus [Vieira et al., 2012] proposed a model integrating crowdsourcing and gamification to solve city problems. Although the work did not specifically mention the term "smart cities" and focused specifically on only one type of specific resource (transit and carpooling), it served as a motivation for the development of the CORE-MM model. This is because one of the objectives of the CORE-MM is that, when applied in cities, it helps to implement smart cities. Therefore, the existence of gamification and crowdsourcing models being applied in cities, even if the term "smart cities" is not mentioned, helps to corroborate the CORE-MM model.

Criteria	Ubibus (Vieira et al., 2012)	mPass WMB (Mirri et al., 2014)	Hefestos (Tavares et al., 2016)	MASC (Telles et al., 2016)	Calgary TIS (Hoar et al., 2010)	PAG-M (Wells et al., 2014)	Makta Hupi (Jylhä et al., 2013)
Utilizes *crowdsourcing*?	Yes	Yes	No	No	No	No	No
Utilizes gamification?	Yes	No	No	No	No	Yes	Yes
Combines *crowdsourcing* and gamification?	Yes	No	No	No	No	No	No
Mentions Smart Cities?	No	Yes (Assistive Smart Cities)	No	Yes (Assistive Smart Cities)	No	No	No
Focused on resource management?	Yes (But limited)	Yes (But limited)	No	No	No	No	No
Resources are city resources?	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Application Area (Types of Resources)	Traffic (Carpooling)	Accessibility (Generation of accessible routes)	Accessibility (Generation of accessible routes)	Accessibility (Generation of accessible routes)	Traffic (Bus Stops and Routes)	Traffic (Sustainable Public Transportation)	Traffic (Sustainable Public Transportation)
Resources Target Audience	Citizens	CwCDs	CnCDs	CnCDs	Citizens	Citizens	Citizens
Target Audience of Resource Management	Anyone	Anyone	System Admins	System Admins	System Admins	System Admins	System Admins

Table 1: Comparative Analysis of Related Work

Antares [Sommer et al., 2015] used crowdsourcing and gamification for transit resources and draws attention to the same reasons as Ubibus [Vieira et al., 2012]. For mPassWMB [Mirri et al., 2014] gamification could have been integrated with crowdsourcing, since, according to the sources researched for this work, gamification motivates users to participate in crowdsourcing.

Hefestos [Tavares et al., 2016] and MASC [Telles et al., 2016] focused on accessibility resources and to map their resources these works did not use crowdsourcing. A crowdsourcing solution could have been used to facilitate and expedite the mapping of resources in these works. In addition, by using crowdsourcing, the scope of mapping could have been increased, and may even include data from the entire city, or from several cities.

CINA [Reinsch et al., 2013] used crowdsourcing to map resources for indoor navigation. However, it could, as in the case of Hefestos [Tavares et al., 2016] and MASC [Telles et al., 2016], have used gamification for the same reasons mentioned in the previous paragraph.

Calgary TIS [Hoar et al., 2010] focused on traffic resources (bus stops and bus routes), although there is collaboration between people - the system administrators - to register resources in the system, this work did not use crowdsourcing. However, a

crowdsourcing solution, rather than an administrative interface for a few administrative users, would have greatly facilitated this resource management.

PAG-M [Wells et al., 2014] and MaktaHupi [Jylhä et al., 2013] use gamification for traffic resources, that is, gamification models being used to solve problems in cities, even if, in this case, the models do not use crowdsourcing and are also focused on a specific resource type (transit resources).

The case of OCTOPUS [Paim et al., 2016] is similar because it uses gamification to help people with chronic non-communicable diseases. Therefore, this work also calls attention to the fact that crowdsourcing could be used, as in the case of Hefestos [Tavares et al., 2016] and MASC [Telles et al., 2016], to help people find the health resources they need.

Criteria	**Antares (Sommer et al., 2015)**	**OCTOPUS (Paim et al., 2016)**	**CINA (Reinsch et al., 2013)**	**Bainbridge, 2015**	**Biegel et al., 2014**	**Nose et al., 2013**	**Smith et al., 2014**	**Info Garden (Maltzahn et al., 2014)**
Utilizes crowdsourcing?	Yes	No	Yes	Yes	Yes	Yes	Yes	Yes
Utilizes gamification?	Yes	Yes	No	Yes	Yes	Yes	Yes	Yes
Combines crowdsourcing and gamification?	Yes	No	No	Yes	Yes	Yes	Yes	Yes
Mentions Smart Cities?	No	No	No	No	No	No	No	No
Focused on resource management?	Yes (But limited)	No	Yes (but aren't cities resources neither generic)	Yes (but aren't cities resources neither generic)	Yes (but aren't cities resources neither generic)	Yes (but aren't cities resources neither generic)	Yes (but aren't cities resources neither generic)	Yes (but aren't cities resources neither generic)
Resources are city resources?	Yes	Yes	Yes	No	No	No	No	No
Application Area (Types of Resources	Traffic (Bus Stops and Routes)	Health resources to CnCDs	Indoor Navigation	Musicology (notes and musical lessons)	Tags in programming codes	Translation in online chats	Feedback in online conversations	Personal Archive
Resources Target Audience	Citizens	People with CnCDs	Citizens	Music scholars	Programmers	Online Chat Users	Online Chat Users	Anyone
Target Audience of Resource Management	Anyone	System Admin	Anyone	Music scholars	Programmers	Anyone	Anyone (Online Chat Users)	Anyone

Table 2: Comparative Analysis of Related Work (continuation)

All other works, [Bainbridge, 2015], [Biegel et al., 2014], [Nose et al., 2013], [Smith et al., 2014] and InfoGarden [Maltzahn et al., 2014], consist on crowdsourcing being integrated with gamification and being used in many different types of problems, although none of them manage city resources.

This work brings a contribution to the crowdsourcing and gamification areas for smart cities because, as described in this section, despite all related works are focused on solving problems of cities, no work was found that is focused on generic resource management for cities. The works are all focused on a specific type of resource. No related work is generic in relation to the resources and areas of application.

In addition, although almost all related works use resources of cities or daily lives of people, none is focused on managing these resources, what is the main objective of CORE-MM. The works that in some way make use of resource management depends, unlike CORE-MM, on an organization or administration system to function. In these works, resource information can be updated and shared, but resources themselves cannot be added by users in the database - neither directly, or neither way.

Crowdsourcing in CORE-MM is done in its own original way and different from the other related works. In this model it is done through the functionalities of check-in, add resource, evaluate resource, update resource, denounce resource and denounce user. It means that the adding, evaluation and update of resources can be done by distance but also by the users being in the location of the resource through check-in. Being present the users earns more points in the gamification than by distance because it is presumed that the data is more accurate. Evaluate a resource means that users can evaluate that the information is true, false, complete or incomplete and also brings points to the user that does the evaluation. Repeated actions – add, update, evaluate – on the same resources don't give points to avoid redundancy of information. And finally, users and resources can be denounced to system admins to keep the information safe.

3 The CORE-MM Model

This section discusses the proposed model as follows. Section 3.1 presents the CORE-MM architecture and Section 3.2 discusses its data types.

3.1 Model Architecture

The CORE-MM model is formed by three client modules (Game, Helper and Admin), three component modules (for search, for gamification and for crowdsourcing), an external data module, a server and a database module.

Figure 1 presents the model architecture of CORE-MM with its 9 modules organized as follows: two client modules executable in a mobile application or through a web interface for personal computers (CORE-MM Helper and CORE-MM Game); a crowdsourcing component, which controls the crowdsourcing features of the model; a gamification component, which controls the gamification functionalities; a resource-searching component that receives search parameters made by users on the clients; the server itself (CORE-MM Server) to manage client requests and update the database; an administrative system (CORE-MM Admin) with some administrative options for the system; the database, which stays on the server, and which is updated by the requests arriving at the server; and a module to receive and connect external data to the model.

Clients (mobile applications and desktop web clients) are responsible for

communication of the user device with the search, gamification and crowdsourcing modules. The CORE-MM client has two versions: CORE-MM Helper, which is the client where users can search for resources through the search component, and CORE-MM Game, which is the client where users can insert and update resources, and communicate with the crowdsourcing components, as well as the search component.

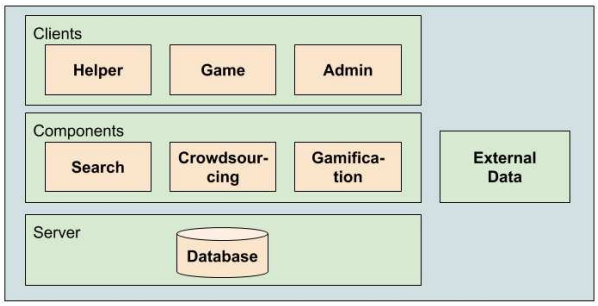

Figure 1: CORE-MM Architecture

The CORE-MM Server manages the server and database functionalities. The Search component manages the search for resources in CORE-MM, receiving queries parameters from the users.

The gamification component of CORE-MM Game is responsible for the gamification system (points, awards, ranking¸ among others) and the crowdsourcing component of CORE-MM Game is responsible for the interaction of clients, by adding and evaluating resources, with the server and the database - that is, it is responsible for managing the resources.

An administrative system, CORE-MM Admin, provides an interface to administrators for administrative and management functions. A module that is responsible for connecting external data to the model, i.e., data that is generated externally to CORE-MM (sensor data, social network data, among others), was also included in the model.

The client, which consists of a web site and a smartphone application, addresses the actions of the users. Users of CORE-MM are of three types: end-users of resources, users participating in crowdsourcing and gamification, and admin users. In the client application interface is where the information of the gamification is displayed: scoring, medals, rankings and more. In the client is possible to carry out registrations and updates of users, resources, maintenance (for the administrator users), among other actions. It is also where the model has its communication methods to send data to the server and also to receive updates. The client is also responsible for the features related to the map.

The server supports all updates in the database. The server receives client requests like: querying the information in the database and entering or modifying data. The server is responsible for responding to the requested information or sending messages if updates or insertions of resources are successfully performed (or when a failure attempt occurs). The server communicates with the other components and

modules and with the actors (users). The server also includes mechanisms for data processing.

The model organizes the flow of information in order to obtain data generated by the actors (users), to treat such data and to make the information available according to their profile (accessibility user, health user and others), that are comprised of optional data provided by them, and searches made by them.

In summary, this architecture is basically composed of a client that displays the information to the users and makes the requests of this information on the server. This, in turn, is responsible for fetching the information in the database and returning it to the client. Finally, the architecture of the model is composed by a web and/or mobile client, the server and the database.

CORE-MM was implemented both to function independently - as a system independent of other models, other systems or other databases, that is, CORE-MM can be implemented in independent clients, independent servers, database and independent data - and it can also be integrated with any other model, system or prototype in which it is considered useful to make use of gamification and crowdsourcing to manage resources such as related works MASC and Hefestos.

3.2 Data Types

One of CORE-MM's primary goals is to motivate users to participate in the collaborative management of cities' resources by sharing information that is useful to the system and which are also useful for people living in cities and looking for resources. Therefore, it is important to define what types of data the CORE-MM model seeks to collect. This section describes what information and types of data it raises through the participation of users with crowdsourcing and gamification.

The information of interest, shared by the users, for the model is classified into three types of resources: dynamic, static and evaluation. Dynamic resources are thus defined and named in relation to the usefulness of it, that is, information considered temporally and/or spatially dynamic. These are information that varies very fast and that, therefore, have utility for some period of time and which needs to be updated frequently for the information to remain useful. Examples of resources of this model may be: schedule and times where buses are in a particular location (traffic), traffic or pedestrian path problems that need to be repaired or are causing temporary delays or roadblocks (transit, public utility), temporary obstacles for people with disabilities (accessibility), among other examples.

Static resources are thus defined and named since they are, unlike dynamic resources, considered to be information that is temporally and / or spatially static, that is, information that comprises durable or permanent data, in relation to the usefulness of the information and, therefore, do not require frequent updates. Examples of resources that are considered static resources may be: bus lines or stops (transit), hospitals (health) location, ramps and other accessibility resources (accessibility, public utility), among others.

The resources that are being added to the system may be new ones, that is, resources being included that do not yet exist in the database, or updates, corrections, and verification of the veracity of the information already registered in the database. These updates and corrections are also made by the users themselves, and the act of making these actions is considered the "evaluation" of the resources, and for this

reason, these resources are named evaluation resources. Finally, the evaluation resources are information entered by users with the purpose of validating the data included by other users (updating, correcting, inserting, appending new information, or verification of the truth of information). As this validation is performed by the users themselves, the more users evaluate the same information, the more reliable they will be. This type of resource is characterized by votes or comments indicating that users agree or disagree with truthfulness, updates or correctness of information.

These are the types of information with which users can collaborate and thus participate in the gamification (winning gifts, points, and more). So, when users want to collaborate by adding resources to the system (thus participating in gamification), they can collaborate by adding information from these resources and evaluating them.

An ontology is proposed to classify data on the resources in the model that form the CORE-MM database. This ontology was developed in the Protégé tool [2016]. Figure 2 shows how the data is represented in a resource ontology in the database. This ontology was developed with the objective of standardizing the elements related to users, resources, locations and mechanics of gamification. The ontology, in addition to resource data in the database, also includes other data that is stored in the database and which are also used for the crowdsourcing, gamification and resource search functionality, which include: user profile data, items and mechanics of gamification, data and location resources, among others. The classes that are marked with the "+" symbol in Figure 2 (eg "Health Resources") can be expanded in their instances (eg "Centennial Hospital" and "People's Pharmacy"), but for facilitate the visualization of the ontology, since each class has many instances, they have not been demonstrated (expanded) in the figure.

Users, by collaborating with information of this type, adding resources to the system, receive points in the gamification (a generic number of points that can be configurable) and, after being validated or evaluated positively by other users, the user receives more points (a generic number of points that can be configurable).

Another type of assessment that users can give is more information about the resources itself (insertion or appending new information about the resource). For example, if they were well attended in a hospital or restaurant, the state of conservation of a hotel or an accessibility resource, among others. These negative evaluations (such as poor service or poor conservation status) are also considered as a contribution from the user who inserted the resource into the system, since it is new information brought into the database that is useful and truthful and in this case generates rewards for the user who entered the resource.

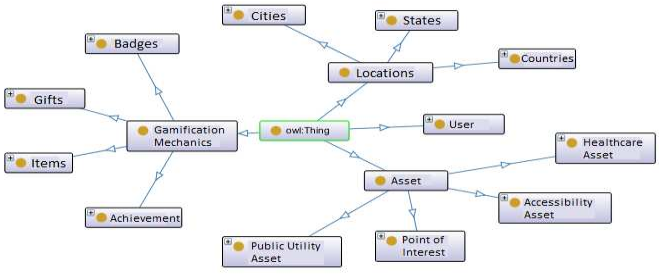

Figure 2: Ontology of data types in the CORE-MM model database

Information about new resources being added should be limited in its redundancy because there is no use for users collaborating with the same information when adding new resources, so users will not receive points for providing information that they have already collaborated with. However, if the user contributes by adding, validating or updating resource information, they will receive a bonus amount of points (a number of points that will also be defined during the implementation phase and evaluation of the prototype) for each updated information, i.e., how much more information updated on a given resource, more points the user will earn. All scores, acquired by users, will be stored in a ranking table. Such a table will demonstrate users with the highest scores and will be available for all users to browse.

4 Implementation and Evaluation

This section discusses the prototype and the evaluation. Section 4.1 describes the prototype and Section 4.2 discusses the user evaluation methodology, the questionnaire applied and the results.

4.1 Implementation aspects

The construction of the prototype was divided into two stages: the design and analysis stage and the implementation stage. For the project stage, the technical documentation necessary to support the implementation stage was generated and, for this purpose, the UML language was used, since, according to Fowler [2004], it is a widely established standard used in software engineering for the creation of diagrams that aim to assist in the modelling of systems and the development of information systems. The implementation stage of the prototype involved the implementation of the CORE-MM client version for crowdsourcing and gamification users, which is called CORE-MM Game, and the CORE-MM client version for resource seeking users, which is called CORE-MM Helper. Both CORE-MM Game and CORE-MM Helper have been deployed in a mobile version for use on mobile devices (such as smartphones and tablets) and a web version for desktop and personal computer use.

In the clients the users make and access their registers in the system. Each user registry is represented by a "user account", and includes the profile of each user. In the user profile, which is accessed through a "username" and password, there is presented data regarding the system (username and personal data), optional data - that is, data that users can fill only if they wish (such as if they have and what type of chronic disease they have or if they have and what type of disability they have), as well as data from the gamification and crowdsourcing system (level, points, and more) and a placeholder for user avatars (which were not implemented in the prototype). In CORE-MM Game registration and login (access with the user account) will be mandatory, and in CORE-MM Helper users will be able to access as a visitor. In addition, clients use tools for map display, view and location data management, which were based on Open Street Maps' open mapping system [OSM, 2018]. For users locations, clients should obtain information through Global Positioning System (GPS), supported by the Android platform, or the World Wide Web Consortium (W3C) geolocation application programming interface API [W3C, 2018], supported through of HTML 5 in web environments. All tests were performed in CORE-MM

Game, since Helper was implemented as an access option (users logged with this option will see the client interface as CORE-MM Helper interface).

The CORE-MM Server has also been implemented. The database, which is composed of tables, relationships and indexes, was developed in MySQL [2018], a relational database management system used to store information and manage access to this information, and that is in the server, has also been implemented. The initial focus of all the components and functionalities are those related to the operation of the systems, crowdsourcing and gamification, because, in addition to being where the objective of this work really is, with these components and functionalities the prototype could already be evaluated. Components and functionalities related to sensors and external data may be implemented in future work. The prototype also has the functionality to be integrated with other models and the integration with MASC [Telles et al., 2016] for the exchange of resource information was implemented.

4.2 Evaluation aspects

The CORE-MM model evaluation consisted on the implementation of a prototype, with the minimum of components of the model's operation, offered to the maximum of possible volunteers to test, and listen their opinions on how their experiences of using the prototype were. In addition, the model evaluation covers its functionality of integration with other models, implemented in this prototype.

In summary, a technology acceptance test was made. Such a test consisted of the voluntary participation of people who have received a presentation and an introduction of the tools, as well as a use test focused on some prototype functionalities. Then, a questionnaire was developed so that these people could give their opinions (such as ease of use, perceived utility, among others), and the data collected could be tabulated in order to evaluate the performance and relevance of the prototype.

In conjunction with the methodology above, it was defined scenarios to simulate the use of the applications as a tool for the management of resources of the cities. This type of experiment is based on a validation strategy called scenario validation, which is one of the approaches used by the scientific community to evaluate ubiquitous environments. This methodology was also applied, with volunteer users executing the scenarios designed for the test. For each scenario, a situation involving one or more players, for crowdsourcing and gamification users, using the CORE-MM Game, as well as a situation involving one or more people seeking resources has been described for CORE-MM Helper. These scenarios are part of the data composition for the simulation that carried out the evaluation of the prototype, and information of the scenarios, resources and users were generated. The scenario for evaluation was the city of São Leopoldo (Rio Grande do Sul, Brazil), including residential, commercial, leisure, squares, downtown areas, university areas and also the city of Pelotas (Rio Grande do Sul, Brazil), where most of the volunteers came from.

It is possible to implement an evaluation with real data contemplating public environments, however, for security reasons and following the evaluation idea used in MASC [Telles et al., 2016], this evaluation was performed only with data generated for the simulation. In order to ensure that the simulation is closest to reality, the prototype uses the Open Street Maps [OSM, 2018] platform because, with this feature, it can simulate real locations and extend the coverage of the CORE-MM

model to any environment or city. To test the integration of CORE-MM with other models, data from MASC were integrated and used in the prototype tests.

The objective of the evaluation was to do simulations of CORE-MM use in activities that are the objectives and daily use tasks of its users: for users of crowdsourcing and gamification is the management of resources and participation in gamification systems; and for the end users of the resources is to help people find resources they need to do their day-to-day activities. In order to make this evaluation, 3 scenarios have been defined, which include creating multi-user simulations by managing resources in cities through the crowdsourcing.

The scenarios were executed using a notebook as a server to run CORE-MM, and also as a client for the applications - CORE-MM Game and CORE-MM Helper. For the tests of the prototype, 10 people of diverse profiles were invited: varied ages, varied schooling, varied areas of activity, and, mainly, varied needs of resources. The profiles of the volunteer users were varied, with the objective of seeking opinions from people who worked in different areas, lived in different areas and had different needs and thus could contribute in different ways. Table 3 shows their profiles.

User	Academic Profile	Occupation
1	Biology PhD	Biology
2	Graduated in Psychology	Psychologist
3	Graduated in Psychology	Psychotherapist
4	Chemistry Technician	Public employee (health area)
5	Doctor with Residency in Psychiatry	Psychiatrist
6	Post graduating in Law	Lawyer
7	Graduating in Control Engineering and Automation	Graduation student
8	Complete high school	Public security
9	Graduated in Computer Engineering	Freelancer
10	Complete high school	Retired health secretary

Table 3: Volunteer User Profiles

The scenarios were run by volunteer users who performed the prototype test as follows: they watched a presentation about the model and the prototype, shortly after they were able to freely test the prototype - for as long as they wanted and performing the actions freely (such as adding resources, assessing resources or seeking resources) - and then the volunteers were presented to the scenarios as a step-by-step and performed the simulation scenarios as if they were the user described in the scenarios. After this, they gave their opinions on the prototype from a questionnaire.

The questionnaire is quantitative and qualitative, and was applied to the volunteers in relation to their opinion about CORE-MM. In this way, the volunteers were free to express their opinions in the way they preferred. The response options for the quantitative questions followed the five-point Likert Scale pattern [Likert, 1932], ranging from the following values (from 1 to 5): (1) Strongly Disagree, (2) Partially Disagree, (3) Indifferent, (4) Partially agree and (5) Totally agree.

The content of the questionnaire was developed based on the concepts of the Technology Acceptance Model (TAM), proposed by Davis [1989] and expanded by Yoon et al. [2007] in his study on wireless network acceptance. The questionnaire consists of statements, where volunteers respond whether they agree or disagree with

them. The following items are considered by the TAM Model as the main influences for the acceptance of a new technology:

• Perceived Usability: degree to which a person believes that technology can help them in their efforts;

• Perceived Utility: degree to which a person believes that the technology could improve their performance in carrying out their activities.

The volunteers were presented to CORE-MM through a demonstration presentation about the model and how the prototype worked and all the concepts about the tool, including the academic concepts involved (gamification, crowdsourcing and smart cities) in the model, and they could ask questions related to its operation. And after this presentation, they were able to test the prototype at will (for as long as they wanted and performing free actions within the system like adding resources, searching for resources and evaluating resources) and then participating in the simulation of the scenarios, performing the scenarios as if they were the test users described in the scenarios. Soon after these tests, they were offered the questionnaire, which consisted of assertions about the model and users could agree or disagree with them using the Likert Scale).

The scenarios included the creation of multi-user simulations managing the cities resources through the model crowdsourcing and gamification system, thus proving the usefulness and the ease of the system and also if the system responds well to the requests, in terms of performance and functionality. For these scenarios, experiments were performed with artificial data sets, generated to perform the simulations. These artificial data sets were assembled to test specific prototype characteristics and will correspond to controlled tests. The purpose of these tests is to validate if the implementation of the model prototype reaches the expected level of effectiveness. The first scenario consisted on simulation of multiple crowdsourcing and gamification users adding resources; the second one simulation of multiple users of crowdsourcing and gamification evaluating resources; and the third one simulation of users with chronic non-communicable diseases seeking and evaluating health resources.

The volunteers were selected through an open call in a social network to participate in the gamification and crowdsourcing model (CORE-MM) evaluation and were willing to participate in such experiment since the beginning. They were attracted by the idea to contribute with a technology scientific study and contribute to testing a new tool that they considered "innovative". Since the prototype was running in a local network, and not in the internet, volunteers needed to be in a travel distance from the testing location and ended up being from the same city (city of Pelotas, Rio Grande do Sul, Brazil). The number of participants was limited to 10 because of physical space limitations where the testing and evaluation was executed.

After the open call for participation, the volunteers were presented to the CORE-MM prototype and also to the concepts involved in the model (smart cities, crowdsourcing and gamification) through a presentation using oral explanation, slides, videos and images and a tutorial using the actual prototype. During and after the presentation, the volunteers could interrupt to ask any question regarding the prototype and its concepts - so they often did. They showed interests in both, and, after the presentation and their questions, they considered themselves able to test and use. This made the volunteers qualified for this evaluation.

They evaluated the main contributions of the research - resource management of cities considering a generic resources approach for smart cities, using crowdsourcing and gamification - through the execution of the simulated scenarios using the prototype and, after the scenarios, free testing and use of the prototype features. The scenarios consisted in the execution of an actions script that are possible to do in the prototype, that is, resource management (find resource, add resource, evaluate resource, update resource and remove resource) and gamification system (check profile, score points, level up and check rankings). Considering the volunteers profile and the method of open call (like a crowdsourcing should be) and the volunteer qualification procedures, we consider the results achieved through the volunteers statistically valid.

The affirmations of the questionnaire for users about the Perceived Use Ease and the affirmations about Perceived System Usability are shown in Table 4. In addition to these statements, other questions of qualitative answers, that is, the discursive questions where users were free to write what they wanted in the answers, were also applied to the volunteers, in order to better understand their opinions about the application. There were four questions with more possibilities for clarification:

- In your opinion, why would people use this application?
- What are the main positive and negative points you can observe in the tool?
- What are the main benefits you see for people in using this tool?
- Other notes (optional).

On the results with the volunteers the percentages had very positive results, mainly in the questions about the Perceived Utility: the lowest score of the Likert Scale that was marked in any one of the questions was "Indifferent", although some divergences and suggestions that were given qualitative issues.

Overall, the percentages, individually, were positive, proving the value of CORE-MM. The users were very confident about the use of CORE-MM and understood the need and the functionality of the application, and, in addition, got motivated about the idea. Concerning the quantitative questions regarding perceived ease of use it can be observed that all questions had practically only positive answers. In these questions, 55% fully agreed and 36.67% agreed partially on the ease of use of the system (91.67% positive responses) and 8.33% indifference in the responses.

In the answers to the quantitative questions we found opinions that collaborated with the positive opinions about the prototype, and those that were indifferent also collaborated since those who did not agree with the affirmations left suggestions. Regarding the issues of ease of use that obtained divergences in the answers have the following opinions: add more search options by resources (name of the resource, address of the resource), which in the prototype is presented as a list of closer resources or by coordinates, and change the language presented in the prototype to an easier (less-technical) language. The first suggestion was already included among the ideas for the system, but they did not have time to enter the prototype until the test date, and the second opinion probably arose from the diversity of profile among the volunteers, but it is a good suggestion for future work, after all the language of the system has to be easy (less technical) for everyone.

	Enunciation	Totally Agree	Partially Agree	Indifferent
	Perceived Ease of Use			
1	CORE-MM Interface is of easy comprehension	60%	30%	10%
2	CORE-MM Interface is of easy utilization	50%	40%	10%
3	In CORE-MM the information is presented in a clear and objective way	50%	30%	20%
4	With little effort, I was able to use the services offered by CORE-MM	40%	60%	0%
5	It was easy to see how CORE-MM's tools work to participate in my city's resource management	70%	30%	0%
6	It was easy to see how the CORE-MM incentive system works (scoring, rankings, rewards, gifts, reputation)	60%	30%	10%
1-6	**% of all questions about Perceived Ease of Use**	**55%**	**36,67%**	**8,33%**
	Perceived Utility			
7	While using CORE-MM, I was able to realize that your resource management is capable of generating consistent data and, in this way, can help people in some way	60%	40%	0%
8	I would provide more data on the resources, participating in the CORE-MM user community	50%	40%	10%
9	I consider important the possibility of sharing and managing resources of a city, made by the users and citizens themselves, through incentives for their participation (scoring, rankings, rewards, gifts, reputation)	70%	30%	0%
10	I consider important the management of resources by CORE-MM applied to Care Resources (accessibility and health)	80%	20%	0%
11	I consider the resource management of a city being done by users and citizens themselves, through incentives for their participation, more acceptable than a model where management is done by an administrative team	60%	40%	0%
12	I think it would be possible to use CORE-MM to manage resources in an entire city, and keep them updated	60%	40%	0%
13	It is an advantage for CORE-MM to be able to handle generic resources of cities, rather than just one type of resource	70%	30%	0%
14	It is an advantage for CORE-MM to be integrable with other systems and models to send and receive resource data	90%	10%	0%
15	CORE-MM's gamification, i.e. CORE-MM's system of incentives, rankings, rewards, gifts, reputation, can be used to manage cities' resources	60%	40%	0%
16	*Crowdsourcing*, that is, CORE-MM's use of collective intelligence and participation of a population, can be used to manage cities' resources	80%	20%	0%
17	CORE-MM can assist in the transformation process of cities in environments where "everything is connected" due to the intensive use of information and communication technologies in cities for urban management and social actions (Smart Cities)	80%	20%	0%
18	CORE-MM can be used to maintain a resource base in Smart Cities (city model described above)	80%	20%	0%
7-18	**% of all questions about Perceived Utility**	**70%**	**29,17%**	**0,83%**

Table 4: Questionnaire Results

Among the positive reactions to ease of use, the most noticeable aspect was the way the map was presented, the fact that the map was global (not restricted to specific locations) and had all the addresses (thanks to the OpenStreetMaps), and the way resources were presented on the map - some volunteers even registered their workplaces in the database and said they liked to see their added resource in the system. In summary, the way resource management is performed has been highly praised, and the way the resource search is conducted has received suggestions for improvements. In these cases, where some people had more difficulties due to the interface of the prototype, it can be concluded that after applying these suggestions, in future work, the negative results would become positive. Regarding the utility of the system, it is perceived that it was even better received than the ease of use. There were 70% of affirmations where the volunteers fully agreed, 29.17% of affirmations where the volunteers were partially agreeable (that is, 99.17% positive responses) and only 0.83% where the volunteers were indifferent in the responses.

Something that was concluded is that crowdsourcing was well perceived and received by all users. However, gamification was better perceived and received by generally younger users and/or more accustomed to information and communication systems technologies in their lives. The level of excitement among volunteers regarding a possible participation in resource management and, in the future, being part of the CORE-MM user community was quite positive and only one volunteer showed less interest than others in this question, so it was only from this user that the indifferent answers came from. Despite this, everyone was interested in a possible future system of gifts for gamification, and a particular user, who considers himself competitive, took an interest in all the gamification features.

Positive opinions that have emerged about the perceived utility of the system revolved around the following issues: facilitating people's lives by helping them find resources, meeting people's needs for resources they are seeking, integrating people and resources through information, the resource management through crowdsourcing to add and update resources, encouragement of people to participate in resource management through gamification, the potential to help people with special needs through accessibility resources, the potential to help people - who are sick and / or in a moment of urgency - through health resources, the ease which the idea of resource management and gamification has been understood, integration with other systems and models, system innovation since they had never been introduced to a similar idea, facilitate people to find themselves in a new location where they do not know anything, the potential for system growth (in number of resources and users), bring agility and time and fuel savings to people seeking resources, the possibility to choose which kind of resource types to show on the map, and the ease of use of resource management.

5 Conclusions and Future Studies

This section presents the conclusions reached with this work. The first one is that there is a scientific opportunity to develop a crowdsourcing model for generic resource management for smart cities and for the areas and resources it encompasses, since no model has been found so far to use crowdsourcing and resource management

for smart cities, neither related works that are generic to the areas and resources it covers.

This paper summarizes the results of a master dissertation [Orrego, 2017] that addressed the model, prototype and evaluation methodology in more details. The dissertation also discussed future works and this section highlights the most relevant ones. The scientific contribution of this work is that CORE-MM proposes a solution to the resource management of cities considering a generic resources approach for smart cities, using crowdsourcing for the resource management and gamification to incentivize people participation on it.

The implementation of the prototype allowed to conclude that the technologies currently available allow the development of a crowdsourcing model for resource management using gamification for smart cities. It was concluded from the results obtained in the tests involving volunteers and scenarios in the prototype, that the CORE-MM model is generic, supporting several different areas and several resource types, since each scenario can present different kinds of necessities and resources (such as accessibility, health and others). It was also concluded from the results that, in addition to being generic, the model, through crowdsourcing, can be extended to several different environments and cities. It was also concluded that the model can be used in large scale, attending large numbers of users, different types of resources and various environments and cities.

Results with volunteers who tested the prototype indicated good perceived ease of use and good perceived utility. These results point positive perspectives regarding the use of the application in possible situations and real locations. With this acceptance by the users, future works can add more information relevant to the research.

CORE-MM is a model that meets the needs of any people living in cities, any people who feel encouraged to participate in crowdsourcing and gamification, any people looking for resources for different reasons, any people who need the resources (accessibility and health, for example), any professionals in the resources areas and the public administration.

As future work, it may initially be suggested to implement in the prototype all other features that have been left out so that tests can continue to be done with even larger groups of users. Another important suggestion for future work would be to increase the number of integrations for receiving and submitting resource data from other models, systems, applications, and even social networks. Preferably integrations that can first bring more Care Resources (accessibility and health, for more testing in these areas) and, secondly, more and more different types of resources (transportation, tourism, among others), thus increasing the number of application areas, user reach and locations where CORE-MM can be tested.

An important goal that could be pursued in the future in this work would be partnerships with organizations, NGOs, city halls or associations that are interested in CORE-MM's resource management idea and willing to donate gifts (in exchange for users' scores) to collaborate with the incentives and rewards of the system. Increase the number of achievements, challenges, rankings and awards, in gamification should also be a goal in future work.

As other future works, more tests involving real users looking for real resources (preferably in the areas of Care Resources - accessibility and health), and with a longer duration (eg days of use), may also be suggested. This could help identify

strengths and weaknesses of CORE-MM and also if it can bring benefits to the day-to-day of these users. Finally, the model allows to be extended to other numerous parameters that can be used in these tests.

Acknowledgments

The authors wish to acknowledge that this work was supported by FAPERGS (Foundation for the Supporting of Research in the State of Rio Grande do Sul), CNPq (National Council for Scientific and Technological Development), and Coordenação de Aperfeiçoamento de Pessoal de Nível Superior - Brasil (CAPES) - Finance Code 001. The authors are also grateful to University of Vale do Rio dos Sinos (UNISINOS) and Mobile Computing Lab (MOBILAB) for embracing this research.

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