WROCLAW UNIVERSITY OF ECONOMICS AND BUSINESS
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CROWDSOURCING IN KNOWLEDGE MANAGEMENT IN SMART CITY PROJECTS

SUMMARY OF DOCTORAL DISSERTATION

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1. Introduction

From the beginning of the second half of the 20th century, rapid technological progress, progressing globalization and migration phenomena from non-urbanized areas to cities have been visible. It is estimated that in 2050, nearly 70% of the world's population will live in cities. Agglomerations are a unique space for human existence. On the one hand, they encourage attractive values, on the other hand, they face problems and challenges for the entire population. In contemporary terms, urbanization should be perceived more broadly as a multidimensional combination of social, demographic, economic or cultural processes.

Currently, the term "smart city" is used more and more often on various levels. It is a term reserved for a certain idea and style of functioning of the city along with the community living in it. Smart cities should not only use modern technologies such as Big Data, IoT (Internet of Things), 5G (fifth-generation cellular technology) or AI (artificial intelligence) but also proactively interact with the inhabitants, notice their problems and solve them effectively. Smart cities are also designed to engage residents in co-governance and social activation.

One of the tools for efficient communication between residents and decision-makers and other stakeholders operating in the city can be crowdsourcing, i.e., the process of commissioning tasks to a wide group of people and proposing solutions to achieve the organizer's stated goals. Currently, smart cities are an extremely important aspect in the development of the entire society, and intra-city communication can be of key importance in ensuring the proper operation of all areas in agglomerations and cities.

The implementation of solutions that improve communication between decision-makers and residents in the smart city area can lead to a better understanding of the needs of residents by the local administration, save time and money and create an engaged community, which may result in collective intelligence. This may play an important role in the current globalization, migration of people from rural areas to cities, and the dynamic development of smart city projects.

2. Structure of dissertation

The work consists of six chapters. The theoretical part includes the first three, while the next three constitute the empirical part of the dissertation.

The first chapter, "Knowledge management processes", discusses definitions and types of knowledge. The role and use of knowledge management processes, the benefits of their implementation, and the barriers that prevent quick implementation are indicated. Models supporting knowledge management were classified. The concepts of intellectual, human, and structural capital were also analyzed.

Chapter two "Characteristics of the smart city concept" concerns the idea of a smart city, i.e., an idea based on the latest information and communication technologies, using efficient urban infrastructure aimed at raising the awareness of residents. The chapter describes in detail the reasons for the development, origin, and evolution of the concept. The classification of the city maturity assessment and the areas of smart city functioning were indicated. Certification awarded to cities after meeting the relevant standards was also analyzed. The discussed topic of sustainable development aims to analyze whether the current concepts of smart cities take into account the doctrine in question and are consistent with it. The author analyzed the projects occurring in the smart city, indicated their examples and problems arising during their implementation and operation. The analyzes were based on the available literature and data from Wroclaw, Montpellier in France and Singapore, a city ranked first in many smart city rankings.

The third chapter entitled "Crowdsourcing as a communication tool" describes the processes of acquiring knowledge from the "crowd", and indicates their components and classifications included in the literature, taking into account crowdsourcing derivatives. The socio-cultural context of crowdsourcing is also quoted. In the following, crowdsourcing tools are described in the example of the cities of Wroclaw and Montpellier (France) and the phenomenon of e-participation is defined. The last subchapter characterizes the idea of participatory budgeting as one of the crowdsourcing tools operating in the area of smart cities.

Chapter four " The crowdsourcing acceptance model" describes the theoretical foundations of the assumptions used and tools supporting the creation of two models based on data from Wroclaw and Montpellier. The chapter indicates the conceptualization of variables, formulates auxiliary hypotheses for the model and also includes a structural model as a graphical support for the analysis of constructs and the relationships between them. The last part of the chapter includes the operationalization of the model and the measurement model with the indicated indicators.

The fifth chapter entitled "Analysis and evaluation of PLS-SEM results" characterizes research samples. Subsequently, reflective and formative measurement models were discussed, and the following were verified: the reliability of the indicators in the model by testing outer loadings, internal consistency using Cronbach's alpha, composite reliability and reliability coefficient, convergent validity by AVE analysis and discriminant validity using the Fornell-Lacker criterion, cross-loading and HTMT analysis. Then, the evaluation of the structural model was analyzed by analyzing the collinearity of the VIF, the significance and validity of the structural model relations by analyzing the path coefficients and significance levels of the given constructs together with the total effects for intermediate dependencies, and the bootstrapping method was used (estimation of the distribution of estimation errors using multiple sampling with sample return). Additional ones have also analyzed the explanatory power of R^2 for endogenous variables of the models, the coefficient f^2 and the power predicted by predictive validity Q^2. The hypotheses posed in the fourth chapter are discussed in the fifth chapter based on the obtained results.

The sixth chapter contains a discussion of individual in-depth interviews conducted with decision-makers and cooperating stakeholders in the cities of Wroclaw and Montpellier, as well as further results of the survey conducted with residents. The chapter aims to compare crowdsourcing from the perspective of decision-makers and residents. It also has a validation function of earlier studies.

In Wroclaw, interviews were conducted with:

- Jakub Mazur (vice-president of Wroclaw).
- Sebastian Wolszczak (deputy director of the Department of Social Participation at the City Hall in Wroclaw).
- Barbara Celebucka (coordinator of the Inne Centrum project implemented by Dom Pokoju, a stakeholder of the city of Wroclaw supporting the building of civil society).

In Montpellier, the in-depth interview was attended by:

- Lucie Garcia (head of participatory budgeting).
- Jérémie Valentin (head of the Open Data project in the Metropolis of Montpellier).
- Eunika Mercier-Laurent (professor at EPITA in Paris, researcher at the University of Reims, activist in Montpellier, coordinator in the International Federation for Information Processing TC12).
- Anne-Sophie Cases (coordinator of the smart city human at home project in Montpellier).

3. The problem statement, research objectives

The main goal of the dissertation is to build a crowdsourcing model in knowledge management in smart city projects. The layout of the work was determined by the thesis of the work and the formulated research questions.

Thus, the author is inclined to the thesis that crowdsourcing in knowledge management in smart city projects is conditioned by both technological and social factors.

Seven research questions were formulated to implement this thesis:

1. What are the types of knowledge and what is their role in the development of intellectual capital?
2. What are smart city projects and in what areas are they implemented?
3. What are the benefits and barriers to the implementation of smart city projects?
4. What crowdsourcing tools are used to manage knowledge in smart city projects?
5. What factors influence the intention to use crowdsourcing in smart city projects?

6. What areas does the smart city concept currently apply to from the perspective of residents?
7. What consequences does the implementation of crowdsourcing tools have for knowledge management in smart city projects?

4. Theoretical basics

With the progressive development of technologies, in particular information and communication technologies (ICT), and their integration into the private and professional lives of users, the decision to accept or reject it is still an open question. In recent years, many researchers have analyzed the development and use of several theories and models of technology acceptance and their effective use.

The Technology Acceptance Model (TAM) was the response to the resulting research gap in this area. It was created by F. Davis. and indicated the need to develop a tool to analyze the factors determining the acceptance of technology. F. Davis created the model to achieve two primary goals:

1. Expanding knowledge in the area of the acceptance process and its connection with the design and implementation of new IT systems.
2. Development of a methodology for user acceptance tests.

V. Venkatesh and F. Davis extended the original TAM model to explain perceived utility and intentions of use in terms of social influence (subjective norms, voluntariness, image) and cognitive instrumental processes (relevance of work, quality of results, demonstrability of results, perceived ease of use). An extended model, referred to as TAM2, has been tested in both voluntary and mandatory use. Intensive research and attempts to expand the TAM model prompted V. Venkatesh et al. to create a new model called UTAUT (Unified Theory of Acceptance and Use of Technology). The new model incorporates constructs from eight models and theories, such as:

1. Theory of Reasoned Action.
2. Technology Acceptance Model.
3. Motivational Model.
4. Theory of Planned Behavior.
5. A model that combines the Technology Acceptance Model and the Theory of Planned Behavior.
6. Model of PC Utilization.
7. Innovation Diffusion Theory.
8. Social Cognitive Theory.

UTAUT suggests that four basic constructs (expected performance, expected effort, social impact, and enabling conditions) are direct determinants of behavioral intention and ultimate behavior and that these constructs are in turn moderated by gender, age, experience, and voluntary use. It is believed that by examining the presence of each of these constructs in the environment, scientists and practitioners will be able to assess an individual's intention to use a particular system, thus enabling the identification of key influences on acceptance in any given context.

In 2012, V. Venkatesh et al. extracted factors from the original UTAUT model for the consumer context and extended them to include the following three factors that improved the prediction of behavioral intentions and usage behavior. They were: hedonic motivation, price value, and habit. The new model was named UTAUT2. First, compared to all previous attempts to extend the model, UTAUT2 was not designed with a specific purpose in mind - the purpose of the theory was to provide an overarching framework for testing technology acceptance. The extension is designed to provide greater precision in explaining behaviors. Secondly, the aim was to propose a behavioral model of consumer acceptance of technology, as opposed to UTAUT, which was developed to study the technology in organizational settings.

One of the techniques used to study and analyze acceptance models is structural equation modeling (SEM). It is a method of multivariate data analysis that can be used to prepare factor analysis, path analysis, and analysis of variance, and covariance. Thanks to it, it is possible to determine the relationships among variables - how much they are dependent, whether and how they affect each other, but also to test a theoretical model containing observable variables (indicators) and their grouping into unobservable variables (latent variables). SEM consists of two fundamental parts of the analysis:

1. Measurement model - a model that examines and verifies how the elements of the scale affect the characteristics of the object of interest. At the same time, it defines the rules for measuring latent variables based on observable indicators and determines how to measure their properties. It allows the observation of the relationship between latent variables and indicators, as well as the verification of previously formulated hypotheses in this area.
2. Structural model - a model defining the pattern of relationships between observable and unobservable variables. The structural model shows how hidden variables are related to each other (indicates structures and their relationships). The location and sequence of constructs are either based on theory, or the researcher's experience and accumulated knowledge, or both.

One of the significant differences between SEM and other methods, which is a great advantage of this type of research, is the ability to estimate and test relationships between constructs. Compared to other general linear models where constructs can only be represented with a single measure and measurement error is not modeled, SEM allows multiple measures to be used to represent the construct and solves the problem of measure-specific error. This difference is important because it allows scientists to determine the constructive validity of the factors. Another difference is the high complexity of evaluating the results obtained after the SEM analysis. Researchers must evaluate multiple test statistics and multiple fit indices to determine whether the model accurately reflects the relationships between the constructs and the observed variables.

Another alternative to the historically more commonly used covariance-based SEM (CB-SEM) when analyzing data using structural equation modeling is PLS-SEM. Partial least squares structural equation modeling (PLS-SEM) is one of the most widely used methods for analyzing multivariate data among business and social scientists. This modeling is based on the method of estimating composite (formative) or latent (reflective) variables.

The structural equation model with hidden constructions has two components. The first component of the structural equation model are measurement models, also referred to as external models. Measurement models include one-way predictive relationships between each latent construct and the associated observed indices. The second component is the structural model, which is referred to as the internal model. It shows the relationships (paths) between the hidden structures. PLS-SEM allows only recursive relations in the structural model (i.e., no causal loops). Therefore, structural paths between hidden structures can only go in one direction.

In the structural model, we distinguish between exogenous and endogenous constructs. The term "exogenous" is used to describe implicit constructs that have no structural pathway relationships pointing to them. Thus, the term "endogenous" describes hidden target constructs in the structural model that are explained by other constructs through the relationships of the structural model (similar to SEM analyses).

5. Research methodology

The following research methods were used in the work:

1. A critical review of world literature (including Polish and French) in the fields of knowledge management, smart city, and crowdsourcing.
2. Survey research conducted in the cities of Wroclaw and Montpellier on a sample of 623 inhabitants.
3. Individual in-depth interviews with city stakeholders and decision-makers in the cities of Wroclaw and Montpellier (7 interviews).
4. Calculations were made in the field of structural modeling based on partial least squares analysis (PLS-SEM).

The model proposed in the example of the cities of Wroclaw and Montpellier consists of 11 constructs, which are: *self-efficacy* (SE), *expected effort* (EE), *perceived security* (PS), *perceived privacy* (PP), *trust in government* (TG), *trust in technology* (TT), *price value* (PV), *self-concern* (SC), *other-orientation* (OO), *group-oriented* (GO), and *behavioral intention* (BI). They were taken from the UTAUT2 model, literature, own research, and in-depth individual interviews which are an integral part of the dissertation.

During the research process, auxiliary hypotheses are indicated:

H1: *Self-efficacy* affects *behavioral intention* in using crowdsourcing tools.
H2: *Effort expectancy* affects *behavioral intention* in using crowdsourcing tools.
H3: *Perceived security* affects *trust in technology* in using crowdsourcing tools.
H4: *Perceived privacy* affects *trust in technology* in the use of crowdsourcing tools.
H5: *Trust in technology* affects *behavioral intention* in using crowdsourcing tools.
H6: *Trust in technology* mediates the relationship between *perceived security*, *perceived privacy,* and *behavioral intention* in using crowdsourcing tools.
H7: *Trust in government* affects *behavioral intention* in using crowdsourcing tools.
H8: *Trust in government* affects *price value* in using crowdsourcing tools.
H9: *Price value* affects b*ehavioral intention* in using crowdsourcing tools.
H10: *Price value* mediates between *trust in government* and *behavioral intention* in using crowdsourcing tools.
H11: *Self-concern* affects *behavioral intention* in using crowdsourcing tools.
H12: *Other orientation* affects *behavioral intention* in using crowdsourcing tools.
H13: *Other orientation* mediates between *group-oriented* and *behavioral intention* in using crowdsourcing tools.
H14: *Group-oriented* affects *other orientation* in using crowdsourcing tools.

Manifesting variables, identified and used in other research works in the scientific literature, were assigned to the operationalization of each latent variable. Thus, in the context of this dissertation, measurement variables for theoretical constructs such as: *self-efficacy* (SE), *expected effort* (EE), *perceived security* (PS), *perceived privacy* (PP), *trust in government* (TG), *trust in technology* (TT), *price value* (PV), were borrowed from the literature on the smart city area and from in-depth interviews with decision-makers and stakeholders included in the work. They include a total of 27 questions. Secondly, manifest variables including theoretical constructions such as: *self-concern* (SC), *other-orientation* (OO), and *group-oriented* (GO) were taken from research on the motives of reporting citizens and are based on in-depth interviews and own experience. They consist of five questions. The construct *behavioral intention* (BI) was built of 3 questions and it is identified with a factor indicating the readiness of an individual to implement a specific behavior. Finally, the measurement of all manifest variables is based on a 7-point Likert scale.

The survey was addressed to the inhabitants of the cities of Wroclaw and Montpellier. It took place on October 1-11, 2021 in Montpellier and on November 2-26, 2021 in Wroclaw. In total, 623 questionnaires were collected (317 questionnaires in Wroclaw and 306 in Montpellier). After rejecting the partially completed questionnaires, 311 questionnaires were obtained in Wroclaw and 299 in Montpellier (610 in total).

The sample size was selected based on indications in the PLS-SEM literature. The *10-times rule* was used in the study, e.g., by M. Mahadzirah et al., J. Hair et al., which suggests that the minimum sample size should be 10 times the number of independent variables in the most complex regression in the PLS path model (considering structural and measurement models). For both models, this value is 7 (latent variables SE, EE, PS, TT, PV, SC, OO to the BI variable), so the minimum sample value for each model is 70.

The tested models were subjected to a detailed analysis, which included the following tests:

1. Evaluation of the reflective measurement model.
   - Reliability of indicators:
     - outer loadings.
   - Internal consistency:
     - Cronbach's alpha,
     - composite reliability ρ_C,
     - reliability coefficient ρ_A.
   - Convergent validity:
     - the average variance extracted.
   - Discriminant Validity:
     - Fornell-Lacker criterion,
     - cross-loadings,
     - heterotrait-monotrait correlation coefficient (HTMT).
2. Assessment of the structural model.
   - Collinearity of models (variance inflation factor VIF).

- Evaluation of the significance and relevance of the structural model:
  - path coefficients,
  - significance level by bootstrapping (estimation of the distribution of estimation errors using multiple sampling with sample return),
- Analysis of the explanatory power of the models R^2.
- Factor f^2.
- Predictive power expressed in predictive validity Q^2.

6. Results and conclusions

In this doctoral thesis it was analyzed the reasons for the development of the smart city concept, presents the genesis and evolution of the concept, taking into account all its generations, and discusses the aspect of sustainable cities and the classification of cities in terms of their maturity. The author listed the areas and scientific models of the smart city found in the literature, as well as the standards defining and normalizing the issues related to them. He also cited exemplary projects based on the literature and data obtained from Wroclaw and Montpellier. He also pointed out the problems that arise during the implementation and operation of smart city projects.

Knowledge management and communication between decision-makers, stakeholders, and residents are extremely important for the proper operation of each municipal unit. The idea of a smart city provides for the possibility of implementing processes supporting the exchange of knowledge in cities, focusing on crowdsourcing activities. Participatory budgeting is an example of a project that fits into urban crowdsourcing.

In the presented work, the author focused on defining the concept of knowledge and indicating its types, taking into account various criteria. He touched on the aspect of the knowledge management process, its role, and its use. He analyzed in detail knowledge management models and strategies, as well as existing barriers. He also discussed issues related to intellectual, human, and structural capital.

In the third chapter, which is the end of the theoretical part, he characterized crowdsourcing processes, indicating the factors necessary for its implementation, occurring derivatives, and structure. He described the tools used in crowdsourcing in the example of the cities of Wroclaw and Montpellier, discussing in detail the participatory budget as a key crowdsourcing tool in the smart city concept.

Based on the analysis of the conducted research, it is concluded that crowdsourcing in knowledge management in smart city projects is conditioned by both technological and social factors.

It should be stated that the work answers all the research questions:

1. The topics related to types of knowledge, knowledge management processes, and human capital development were analyzed.
2. A detailed analysis of the aspects of smart cities was made and smart city projects were defined on the example of Wroclaw and Montpellier, as well as Singapore, which occupies leading positions in smart city rankings, and based on available literature.
3. The benefits and barriers occurring during the implementation of smart city projects have been demonstrated.
4. The crowdsourcing tools used to support knowledge management in smart city projects are described in the example of Wroclaw and Montpellier.
5. Auxiliary hypotheses were developed and factors influencing the intention to use crowdsourcing in smart city projects were determined.
6. Areas that are perceived as elements of a smart city from the perspective of residents have been indicated.
7. Based on in-depth interviews with decision-makers and stakeholders, it was shown that the dissemination of crowdsourcing systems leads to the diffusion of knowledge between decision-makers, stakeholders, and residents, and this translates into reducing the information gap in the city.

In both models, the author showed that the factors that affect the willingness of residents to share knowledge and their involvement in crowdsourcing projects in the smart city area are: *trust in technology* and *self-concern* to the greatest extent, *self-efficacy* to average extent effectiveness, *expected effort*, *other-orientation*, not too much *trust in government* (local administration) and *price value*. In addition, it was observed a large effect of *perceived security* and *perceived privacy* on *trust in technology*, the effect of *trust in government* on *price value*, and the average effect of *group-oriented* on *other orientation*.

In the first model for the data from Wroclaw, all hypotheses were confirmed, while in the case of the validation model for the data from Montpellier, in two cases the results are not statistically significant: the relationship between *perceived security* (PS) with *behavioral intention* (BI) and *group-oriented* (GO) with *behavioral intention* (BI) the significance level condition for $p<0.05$ is not met (p values are 0.066 and 0.13, respectively), so they are not statistically significant. In the case of the validation model, the results for hypotheses H6 and H13 are not statistically significant. The rest of the hypotheses were confirmed.

The author reviewed the literature, conducted surveys, conducted in-depth individual interviews, and analyzed archival data on participatory budgets regarding the method of crowdsourcing in the smart city area. Currently, it is noticeable that the voting process is almost completely carried out remotely, using electronic ICT tools, so technological factors are partly determinants of the use of crowdsourcing by residents.

The dissertation in question gives a practical opportunity to use the results obtained in the model to determine the factors affecting the willingness of residents to share knowledge, affecting their involvement and motivation in crowdsourcing projects. This knowledge can be used by decision-makers and stakeholders in smart cities. The results obtained from surveys and in-depth interviews indicate the usefulness of the model for further development of the smart city area and knowledge management in cities.

The implementation of the model in question in cities in the smart city area may contribute to the dissemination of participatory budgeting, which ultimately leads to the reduction of the information gap between decision-makers and residents. This also translates into increased well-being of individuals and social groups thanks to the implemented projects requested by residents.

The topic of smart cities has been discussed in the literature many times, and researchers have verified, among others, the attitude of smart city residents to the use of Internet applications using the UTAUT model (Y. Popova, D. Zagulova), factors affecting the development and adoption of smart city services using the TAM model (J. Choi) or the acceptance of smart services were studied based on IoT, oriented towards sustainable development (F. Bestepe, S. Yildirim). The dissertation fills a defined research gap, moreover, it complements the previously rarely undertaken research in the field of formulating a crowdsourcing model in knowledge management in smart city projects.

The research and considerations presented in the work do not exhaust all the issues related to the importance of crowdsourcing in knowledge management in the smart city area. In the future, the use of the implemented model should be empirically examined, and its usefulness and quality of use should be analyzed.