Informational-analytic methods for sociotechnical system on the basic of smart city concept

Anatoly D. Khomonenko[a], Natalia V. Ivanova[a] and Heikki Ruohomaa[b]

[a] *Emperor Alexander I St. Petersburg State Transport University, 9 Moskovsky pr., Saint Petersburg, 190031, Russian Federation*
[b] *Häme University of Applied Sciences (HAMK), Hämeenlinna, 13101, Finland*

Abstract
The issues related to various methods of analyzing indicators and data of socio-technical systems to optimize the choice of a strategy for interaction of citizens and organizations with technical systems (sensors, video cameras, robots, computer and mobile devices, as well as information technologies) during the period of digital transformation and Implementation of Smart City concept inside smart ecosystem interoperability socio and technical components form one hand, and data fusion between heterogeneous components from different areas from another hand combining of socio and technical analytics throughout Smart City Life Cycle are considered. In article risk factors related to the activities of citizens, organizations, administrative and financial structures are also touched upon by the example of the choice of the Smart City concept. Methods of analysis, selection and implementation of the concept of a smart city are demonstrated using examples of the experience of international projects in the field of application of various methods of analysis.

Keywords 1
socio-technical approach, smart city concept, latent-semantic analysis, quality indicators, informational-analytic methods.

1. Introduction

Digital transformation and industry 4.0 discover significant challenges connecting the driving forces and key technologies enabling to consider and combine of the technological, organizational and management directions as unit ecosystem.

In nearest future computers will connect and communicate with one another, in the end, to make decisions without human involvement or to help people to make decisions in complicated situations as well. Everything including both virtual and physical world will be connected and will transform whole economies and societies and behavior of people. In this case we have to take the attention to socio-technical approach to find the best match between the technological and social components of a system to organize their joint interconnection and iterability.

A socio-technical system is a network of interconnected elements comprising groups of people and technology that functions as one

Models and Methods for Researching Information Systems in Transport, Dec. 11-12, St. Petersburg, Russia
EMAIL: khomon@mail.ru (A.D. Khomonenko);
nataliv62@gmail.com (N.V. Ivanova);
heikki.ruohomaa@hamk.fiPersonal (H. Ruohomaa)
ORCID: 0000-0003-0411-258X (A.D. Khomonenko);
0000-0003-3463-2770 (N.V. Ivanova);
0000-0002-4663-5349 (H. Ruohomaa)

simple or complex system designed to achieve specific goals.

The main idea is to show how it is possible combine the existing methods of analysis and diagnostics (both from mathematics and social science as well) to understand our future and how can we and further generation to exist, work, interconnect, live, develop together with new smart and digital devices during whole life cycle.

It is important to understand advantages and disadvantages, opportunities, threats and risks of our smart future on the basic of combination of these socio and technical analytics.

One of example of socio-technical approach implementation is the smart city concept which can bring together technology, government and different layers of society, utilizing technological enablers, such as the internet of things (IoT) and artificial intelligence (AI).

2. Smart city concept as a socio-technical approach implementation

The smart city concept represents new ways both of organizing city functions and urban life for environmental purposes as well, based on digitalization [1] and derives from the intersection of studies in urbanism and information and communication technology (ICT), combined with the dimensions of creativity and humanity [2]. In this connection nowadays considering and analyzing Smart City as social-technical system and thinking how should we organize citizen's life in the megalopolis using and implementing Smart City concept is quite actual.

The main components of the future Smart City and their new roles present on the Figure 1, together with the ecosystems formed by smart cities, establish a framework for a new kind of development in urban areas.

The Smart City strategy based on the next smart technologies (see Figure 2): IoT sensors, video cameras, social media, other inputs, and works as a nervous system, providing the city operator and citizens with on-line feedback so they can make informed decisions.

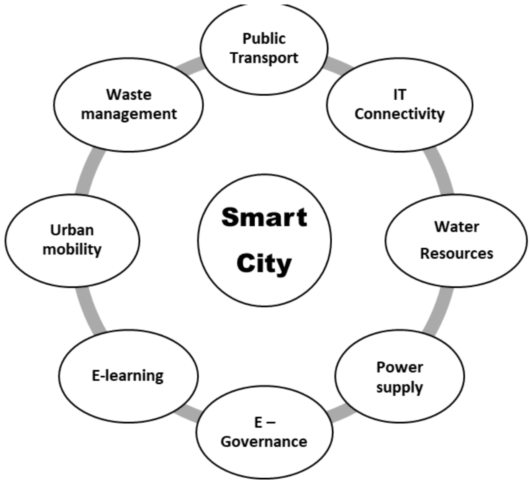

Figure 1: Main Components of the future Smart City adapted from [3]

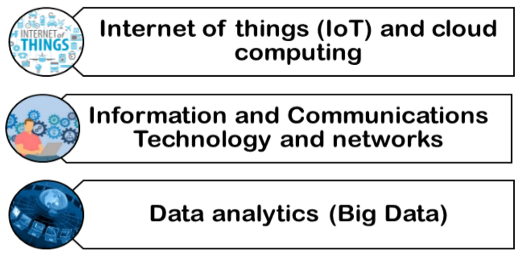

Figure 2: Main smart technologies for Smart City concept implementation

It is important on the base of data and those technologies during whole life cycle to analyze and improve on the basic of Smart City approach as an example of socio-technical and show how:

- smart technologies can help society;
- make technic systems and technologies more efficient;
- combine successfully society and technology into socio-technical performance.

In the same time Smart City can be considered how not only Socio-Technical system but as Socio-Cyber-Physical system (SCPS) as well that is an information technology concept that implies the integration of computing resources into physical entities of any kind, including biological and man-made objects [4,5]. In cyber-physical systems, the computational component is distributed throughout the physical system, which is its carrier, and is synergistically linked with its constituent elements.

One problem of this research is achieved in the process of considering of three issues:

1. Definition of the current state of knowledge of SCPS.
2. As a result of the fact that a person is presented in SCPS, it is possible to obtain fundamentally new knowledge.
3. Some problems associated with communication in SCPS.

3. Human factors and social Aspects human-devices smart interaction

SCPS approach allows to understand interconnection between human and smart devices in Smart City concept. All cyber physical systems operate for humans and support by humans providing human and smart devises interconnection. In this connection, taking into account of social aspects in their development during development and operation renders these systems much more effective.

The main problems of interaction of SCPS problems are related to different types of communications (see Figure 3).

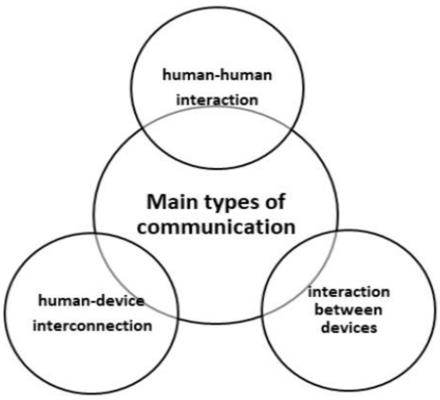

Figure 3: Main types of communication in SCPS

The development of multimodal interfaces for interaction between smart devices and a person is a quite important technological process and requires a social technical approach. Such multimodal interfaces base on such technologies as:

- the human-speech interpretation,
- the human-gesture interpretation,
- the human-gaze interpretation,
- the human-movement patterns,
- and other behavioral cues.

Such multimodal inter insurance design requires a human-oriented approach to eliminate the shortcomings of interaction between smart devices and a person.

In addition, this development will help to solve the main problem of SCPS which means to increase reliability by duplicating information through several channels. Such problems of SCPS in accordance with the type of communication include:

- Planning and navigation through previously unknown territory;
- The problem of energy;
- Security;
- Anthropomorphic (humanoid) manipulations;
- Intuitive human-machine interfaces for the implementation of interaction; communication between a human, a robot or a SCPS.

It is very important to understand specifics of human behavior in Smart City concept dividing at the human dimension on two levels:

1. Micro level: interactions of people with smart technology, other company's and other persons, hence the realm of Human Factors (with capital letters) research in the traditional sense, but also organizational studies, communication research and possibly others.
2. Macro level: interactions between smart industry institutions, performed by their members/staff, as analyzed by political science, political economy, history of economy and technology or organizational studies.

The distinction between the "micro" and "macro" levels has been proven useful in the data analysis.

4. Socio and technical analytics throughout Smart City Life Cycle

In the theoretical framework it is important in this stage to build the readiness for the change by developing an innovation, and identification the innovation process in all sectors/industries, since innovation will often take place at interfaces of different sectors/industries. At the same time, it is necessary to understand and take into account the human behavioral factor during the process of change the business landscape. Implementation the full promise of Smart City inside smart ecosystem will require interoperability socio and technical components form one hand, and data fusion between heterogeneous components from different areas from another hand combining of socio and technical analytics throughout Smart City Life Cycle, for example (see Figure 4):

- Life Cycle Data Analytics and statistics;
- Mathematical decision support methods;
- Information Analytics (=Business Analytics);
- SWOT, PESTEL, SHELL analysis;
- Indicators analysis;
- And etc.

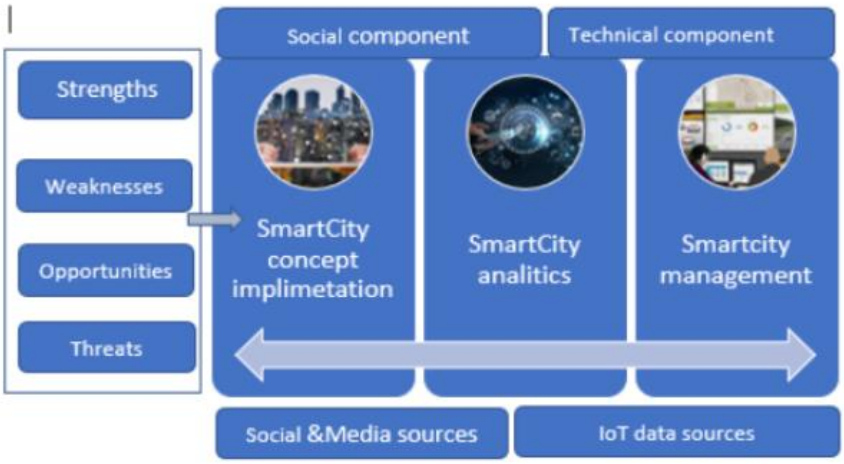

Figure 4: Socio and technical analytics throughout Smart City Life Cycle (Data Analytics and statistics)

Using SWOT analysis principles for example on the basic of gathered data from both socio&media sources and IoT data source as well it is possible to understand the current situation regarding to prior Smart City results concerning inversibility and interconnection between social and technical components on the whole life cycle. It is possible to understand a clear picture concerning the difficulties and favorable issues in the Smart City concept implementation and socio-technical interaction.

4.1. The data processing approach from social networks for the public opinion and smart city indicators

Approach to data processing from social networks for the public opinion detecting about smart services implementation during the whole life-cycle. One of an important indicator of the state of the of socio-technical interconnection in Smart City concept implementation is public opinion (PO). Monitoring and analyzing of PO is an important and actual management tool, which is actively used by different statistics and analytics agencies and organizations. Such approach is proposed to identify public opinion about Smart City services on the basis of large data extracted from social networks.

The data analysis of factors influencing the PO makes it possible to identify areas of greatest concern for the city population, indicators that determine the advantages and disadvantages of smart technologies implementation, socio-technical interconnection taking into account the behavioral factor and including steps of the PO identification about smart technologies implementation during the whole life-cycle as on Figure 5.

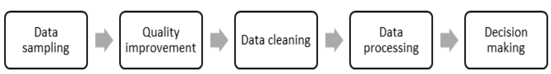

Figure 5: Steps of the of the PO identification

and the data obtained analyzing during the life-cycle

Approach to data processing mostly is based on the latent-semantic analysis (LSA) and automatic detection of semantic links between documents [6] and consists of steps (Figure 5).

Smart Indicators for analysis on the basic of international standard are presented in the Table 1 [7].

Table 1
Smart City indicators

№	Group of indicators
1.	Citizen service
2.	Efficient governance
3.	Liveable environment
4.	Smart facility
5.	Information resource
6.	Cyber security

4.2. Steps of the data processing approach from social networks for the public opinion and Smart City indicators

There are six steps for the data processing approach realization.

1. Creation of A term-document matrix, the elements of the matrix contain the frequency of use of terms in documents.
2. Forming of the decomposition of the obtained term-document **A** matrix into the product of three matrices:

$$A = USV^T \quad , \qquad (1)$$

where
A – the original matrix,
U and V^T – orthogonal matrices,
S – the matrix on whose diagonal hosts the singular coefficients.

Note: The LSA method displays documents and individual words in "semantic space", in which all comparisons are made. As a result, subset of texts from a single space is get.

3. Identification of machine-generated texts.

Identification of the origin of the text is a task that can be formally described as follows:

$$V = (a', A) = \min[D(a', a_i)]; i = 1..n,$$

where

$$a' = (a'_1, a'_2, ..., a'_m); \; a_i = (a_{i1}, a_{i2}, ..., a_{im}).$$

It is decided that the input text is assigned to the *i*-th class if the following expression is fulfilled:

$$V = (a', A) = D(a', a_i);$$
$$V(a', A) \le l,$$

In order to formalize this problem, additional notations are introduced:

- a' is a set of calculated values for the text characteristics of some input text t, the origin of which is to be determined, t ∈ T;

- $V(a', A)$ is a measure of the evaluation of the attribution of the input text to a class of texts with a known origin;

- $D(a', a_i)$ - a measure of distance between the input text and the i-th class of texts of known authorship, represented as a measure of distance between the vectors: a' and a_i;

- l is the threshold value of the distance between the vector of values of text characteristics of the input text a' and the invariant vector of the i-th class of text with a known origin ai such that the maximum value of the measure $D(a', a_i)$ shall not exceed l for $i = 1..n$ [2].

4. Clustering of texts on the basis of machine generation continues the procedure for data cleaning.
5. Classification of text fragments by tonality.

In order to improve the quality of the analysis, it is necessary to carry out clustering on the feedbacks tonality.

This allows you to limit the search for information by a small subset of documents. In solving the problems of automatic classification of texts are used following methods:

- information retrieval (IR);
- machine learning (ML).

It is used less strict clustering (than the common K-means algorithm) based on the c-means algorithm (because we are dealing with reviews). A special feature of the algorithm is the using of a fuzzy membership matrix. It is required to choose the coefficient of fuzziness and number of clusters.

On the basic of the above mention formula for calculating the centers of clusters is:

$$c_l^{(i)} = \sum_{j=1}^{d} \left(u_{ij}^{(l-1)}\right)^w m_j \Big/ \sum_{j=1}^{d} \left(u_{ij}^{(l-1)}\right)^w, 1 \le i \le c.$$

Where (in our case) the following values are taken:

the exponential weight (m) = 2,

the number of clusters 3 (negative, positive, neutral).

6. Data processing.

Data processing is built on the general sampling of all clusters, a frequency analysis of empirically derived performance indicators is carried out. For each of them a dictionary of synonyms, synonymous phrases characteristic for the language of the audience in question (students and senior students) is compiled. The evaluation of each factor was made according to the degree of belonging to one of the clusters.

5. An Example of the socio-technical analysis on the basic of the data processing from social networks, SWOT and PEST analysis

An assessment of current public opinion about Smart City concept implementation can be provide on the basis of feedback from research specialists, business societies and governmental representatives published on Internet resources. After all the procedures of cleaning and improving the quality of extracted data, a frequency analysis of the words in the texts is carried out. The whole array of texts can be divided into three groups for example:

- the questions of research specialists (it can be questionnaires);
- the feedback from business societies;
- governmental representatives.

Every Questioner consists of questions concerning implementations of every of smart technologies which are measured by Smart Indicators (see Table 1) and Socio and technical analytics throughout Smart City Life Cycle on the basic of SWOT and PESTEL analysis (see Figure 4). The programming instrument which can allow to carry out analysis during whole life cycle of Smart City concept implementation can be created, used and support new technologies introduction.

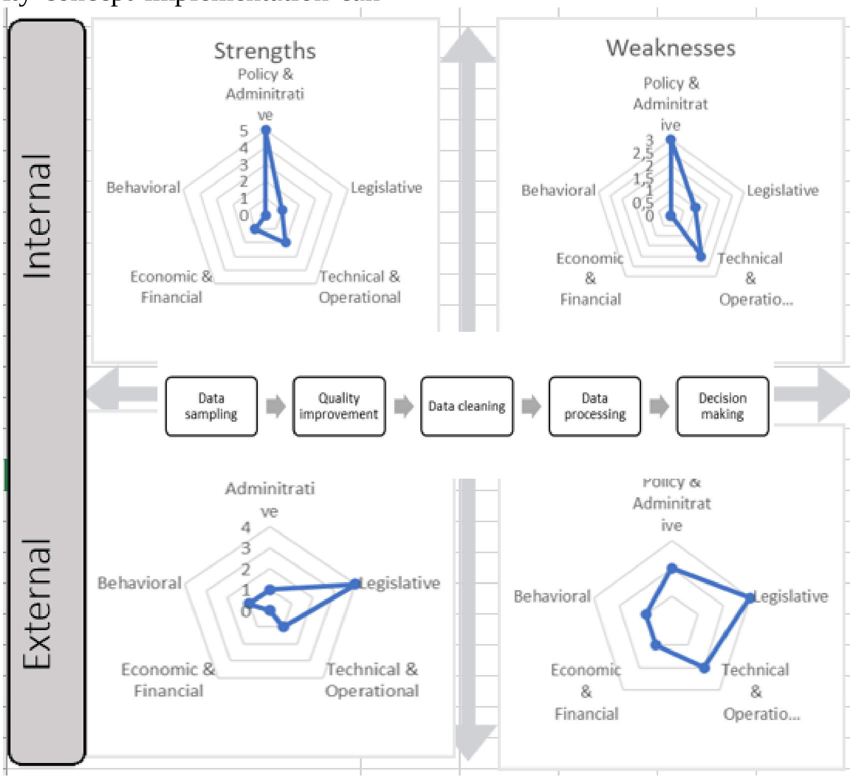

Figure 6: An Example of Socio and technical analytics throughout Smart City Life Cycle on the basic of unit of different analysis approaches

The main results of the SMART CITIES SWOT analysis, listing the factors with the highest impact values in each of the sections (strengths, weaknesses, opportunities and threats) are summarized as on Figure 6 for every indicator (Table 1).

6. Smart City: Risk factors and implications

According to the United Nations, Smart Cities will have 50 billion devices connected to the Internet by 2020. This number of connected devices also has its disadvantages:

it result is a significant reduction of privacy because it is possible to know at any time:

- where the citizens are,
- what they are doing,
- who they are with,
- etc.

It also lead's serious cyber risks which can be analyzed using above mention approaches. There is no doubt regarding the benefits of Smart Cities but it needs to keep in mind that their evolution must go hand in hand with a total, and 100% secure protection.

7. Conclusion

The concepts of building a Smart City and approaches is to organize interaction between participants in a Smart City considered in this article can be used to improve the efficiency and safety of its life. To obtain the initial data to improve the life of a smart city, it is advisable to use an assessment of current public opinion on the basis of feedback from research specialists, business societies and governmental representatives published on Internet resources. Implementation the full promise of Smart City inside smart ecosystem will require combining of socio and technical analytics throughout Smart City Life Cycle: data analytics and statistics; mathematical decision support methods; information analytics (=business analytics); SWOT, PESTEL, SHELL analysis; indicators analysis; and etc.

References

[1] Öberg, C., Graham, G., & Hennelly, P. (2017). Smart cities. IMP Journal, 11 (3), 468-484. https://doi.org/10.1108/imp-06-2015-0024.

[2] Nam Pereira, V. G. et al. 2017. Increasing collaboration and participation in smart city governance: a cross-case analysis of smart city initiatives. Information Technology for Development, 23(3): 526–553

[3] Giffinger R., Hofer A., Sanchez Guzman S., M. Ecker (Hrg.): "Transformation Processes in Metropolitan Development"; Ueberreuter Print & Packaging GmbH, Wien, 2017, ISBN: 978-3-902707-39-0; 204.

[4] An Anthology of Theories and Models of Design Edition: First Chapter: 5. Publisher: Spinger Verlag London. Editors: A. Chakrabarti and L. T. M. Blessing. (Chapter Imre Horvath. What the Design Theory of Social-Cyber-Physical Systems Must Describe, Explain and Predict?) DOI: 10.1007/978-1-4471-6338-1_2.

[5] Ekaterina Shcherbakova and Boris Sokolov. Problems of Socio-Cyber-Physical Systems Development and Implementation: State-of-Art and Directs of Research. Advances in Intelligent Systems and Computing. Vol.1226. Applied Informatics and Cybernetics in Intelligent Systems Proceedings of the 9th Computer Science On-line Conference 2020, Volume 3. Springer. Pp. 597-606.

[6] A. D. Khomonenko, V. L. Dashonok, K. A. Ivanova, D. T. Kassymova. Approach to processing of data from social networks for detecting public opinion on quality of educational services. Procceding of 2017 XX IEEE International Conference on Soft Computing and Measurements (SCM), 24-26 May 2017,ore: 07 July 2017 DOI: 10.1109/SCM.2017.7970707, Publisher: IEEE, Conference Location: St. Petersburg, Russia.

[7] ISO/IEC 30146:2019 - Information technology -- Smart city ICT indicators (iteh.ai).