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Smart Cities and ICT – Insights from the Morgenstadt project

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1 ABSTRACT

According to the United Nations, 60% of the world's population will live in urban areas by 2030 (United Nations 2012). While many cities around the world are growing and expanding, at the same time, a big number of cities in the northern hemisphere is facing reverse trends, e.g. caused by the demographic change. As a result of these trends and the comprehensive globalization, cities are competing within a global market for companies and well educated inhabitants. As an additional challenge, the climate change revealed his powerful forces during the last decades as seen in hurricanes Katrina and Sandy in 2005 respectively 2012 or typhoon Haiyan in 2013.

In this context, cities are facing an extremely difficult assignment: an innovative sustainable development of the city, including ecologic, economic and social dimensions. This task includes two central requirements, making the city livable on the one hand and resilient against external factors as natural disasters or other crises on the other. This paper outlines innovative approaches of cities all over the world, in order to achieve the goal of a sustainable city of tomorrow, concentrating on the contribution of innovative information and communication technologies (ICT).

The paper is based on an interdisciplinary long-term research project called "Morgenstadt: City Insights" (m:ci), which analyzed innovative and sustainable solutions and projects of the city sectors mobility, water infrastructure, production and logistics, governance, buildings, energy, security and ICT in six leading cities around the world in order to identify common characteristics and structures of success stories.

Therefore, the paper first presents the research methodology of the m:ci project, followed by an overview of the examined sectors, projects and cities. Subsequently the key findings regarding the ICT sector will be presented and the role of ICT for an innovative and sustainable city development will be outlined. In this context it will be elaborated for instance how ICT enables innovative solutions of other sectors and to which extent the collection and procession of urban data contributes to a sustainable development. Finally, the paper discusses the transferability of the identified approaches and tries to illustrate possible strategies to implement such innovative and sustainable solutions.

2 MORGENSTADT: CITY INSIGHTS PROJECT

This chapter provides a brief introduction into the m:ci project. At first the underlying idea for the project is outlined, followed by the developed and applied research methodology.

2.1 Idea

The urban knowledge economy is facing a tremendous transformation that will affect the society technologically, organisationally and systemically. Individual technological sectors, such as energy or mobility, will be affected. But since these sectors are highly cross linked, especially in cities and urban regions, the change in one sector will affect all others and the urban system itself as well. To understand the interdependent links between the urban sectors the Fraunhofer Society launched the innovation network m:ci. For this system research initiative, 12 Fraunhofer institutes work together to investigate innovative solutions for a sustainable city. To achieve this goal a holistic research approach was developed in order to analyze the city system in its interdependent structure (Kalisch et al. 2013).

The main goal of the first period (2012-2013) of the m:ci project was to identify the status quo and establish a starting point for the research and development of innovations for urban systems. Based on the findings of the first period and the systemic understanding of urban areas, the second period (2014-2015) will focus on discovering and implementing systemic approaches that successfully respond to the increasing problems of the selected technology fields in leading cities. By detecting and analyzing innovative but already field-tested approaches, their feasibility for other complex environments and demands for an urban future will be evaluated. To verify this expertise will be pooled to develop smart and individually customized strategies

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together with our network partners from industries and cities, aiming at the future requirements for further concepts' efficient implementation.

2.2 Methodology

The m:ci project follows a transdisciplinary research approach, its first phase has been divided in seven phases (see Figure 1). At first more than 270 global good practicees in more than 250 cities around the world that were applicable to bring the city forward towards a liveable, resilient, zero-waste and CO2 free city were studied. The examples were ranked by researchers from the corresponding field by innovative technologies, business models, forms of organization used, and the transferability to other cities. Based upon this assessment 80 solutions were defined as best practices. All 80 best practices were evaluated in a systemic way which included assessment of core sustainability indicators on social, economic and environmental impact and a cross-sectoral analysis of systemic interfaces with other sectors.

The amount of identified best practices per city served as reference for the city ranking. Further, a meta-analysis of cities that appeared in different indices lists was conducted. Based on this list a meta-ranking of the cities was compiled that reflect their overall performance. The final ranking was realized by integrating the best practice-ranking (70%) and the global meta-ranking (30%) into one list of inspiring and leading global cities on the field of urban sustainability. The first 24 cities of the final ranking were taken as base items for defining the top 12 list. This was done by referring to the preferences of project partners, to a fair regional distribution and to a good distribution of sector-specific best practices. Based on the top 12 list the project partners choosed six cities (Berlin, Coppenhagen, Freiburg im Breisgau, New York, Singapure and Tokyo) that were studied on-site (phase 1 and 2 in Figure 1).

Prior the two-week research visit the mayors offices were contacted and asked to support the fieldwork with a letter of recommendation and support. Aditionally several other locally based institutions like universities, German associations etc. were also contacted in advance to request support in lining up interviews with the persons that were responsible for the studied best practice examples. The m:ci project team defined 15-65 indicators with the associated data for each sector in the given city and saved this information in a relational database that was developed for this project. The same was done with information and data that were collected from each studied practice example in the city.

Prepared with the results of this desktop research, a group of Fraunhofer researchers stayed in each of the six cities for two weeks and mainly conducted narrative interviews with relevant actors within each practice example. The interviews, typically 1.5 hours in duration, were conducted on the basis of a part standardized questionnaire which was adapted to each interview. The interviews were recorded, when permitted, and later analyzed.

The practice examples were, whenever possible, viewed and visited, in order to gain a personal impression. Each night the involved researchers came together to share the insights they gained this day. This step was not done for a group dynamic reason only but to gain transdisciplinary insights from the other researchers. By sharing and discussing the experiences the researchers were challanged to view the studied example from their own sector from another perspective and also to rethink the projects of other sectors from ones own perspective (Roehl et al. 2012; Bojer et al. 2008).

Additionally, all actors that were involved in the city's key projects were invited to an evening event during which the project, as well as the researcher's first impressions of the city, were presented. The city's sustainability initiatives were discussed during a panel discussion and a subsequent reception. The feedback of the participants was incorporated in the analysis and accounted in the following interviews. During the so-called "Morgenstadt: City Labs" several hypotheses relating the examined practice examples were developed following a defined methology and discussed with the m:ci project partners. The discussions served to help the researchers recognize inherent patterns in the implementation of projects and solution approaches (phase 3 and 4 in Figure 1).

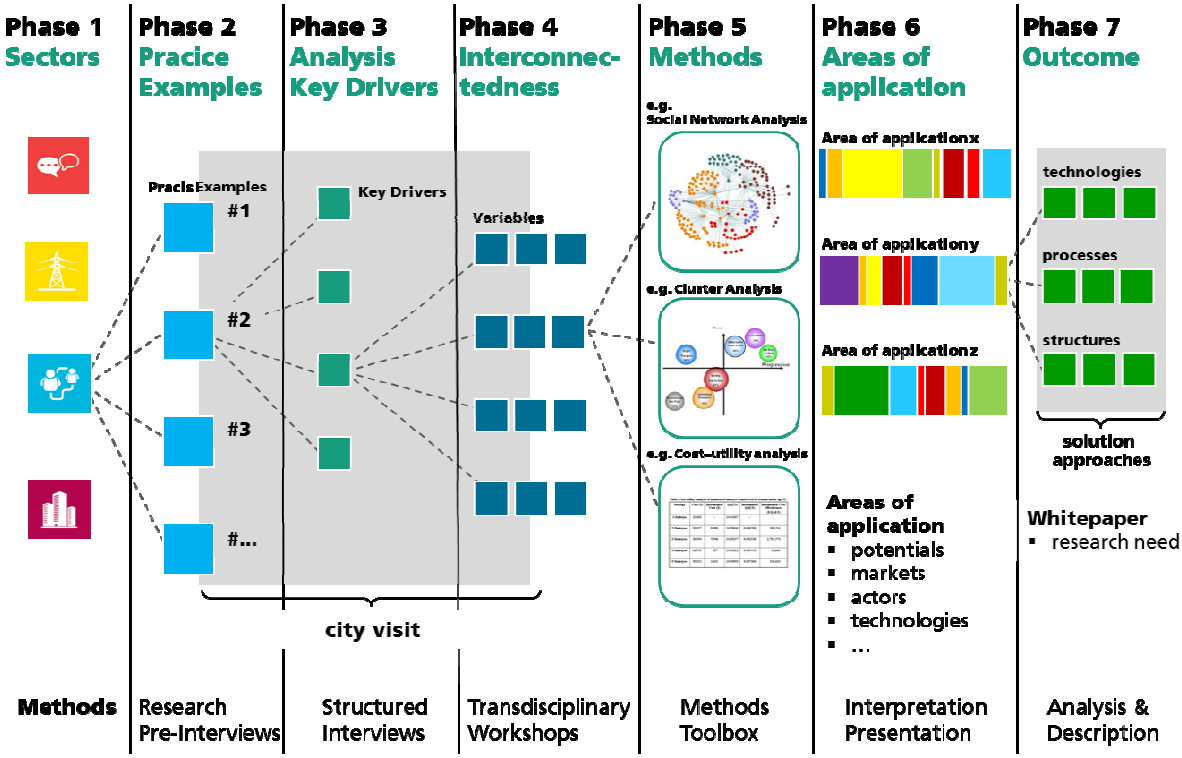

Figure 1: Overview of the research process from sectors to areas of application (Kalisch et al. 2013)

Based on the qualitative interviews and available quantitative data, impact factors for certain processes were indentified. The analysis of impact factors uncovers why a certain progress happens in a particular way in a specific urban system. Accordingly they describe general forces that push or hinder the process of sustainable development on many different levels. The identification of impact factors is complex and requires a transdisciplinary reflection by the researchers. The researchers therefore reflected every day the identified drivers and framework conditions. One important tool to do this were collaborative mind-maps to structure the identified factors. Further, a mixed methods approach was applied, utilizing social network analysis and cluster analysis (phase 5 and 6 in Figure 1).

Starting from a three-level-approach (indicators, impact factors and action fields) of urban systems analysis the m:ci research network developed a first generic model for sustainable urban development (see Figure 2).

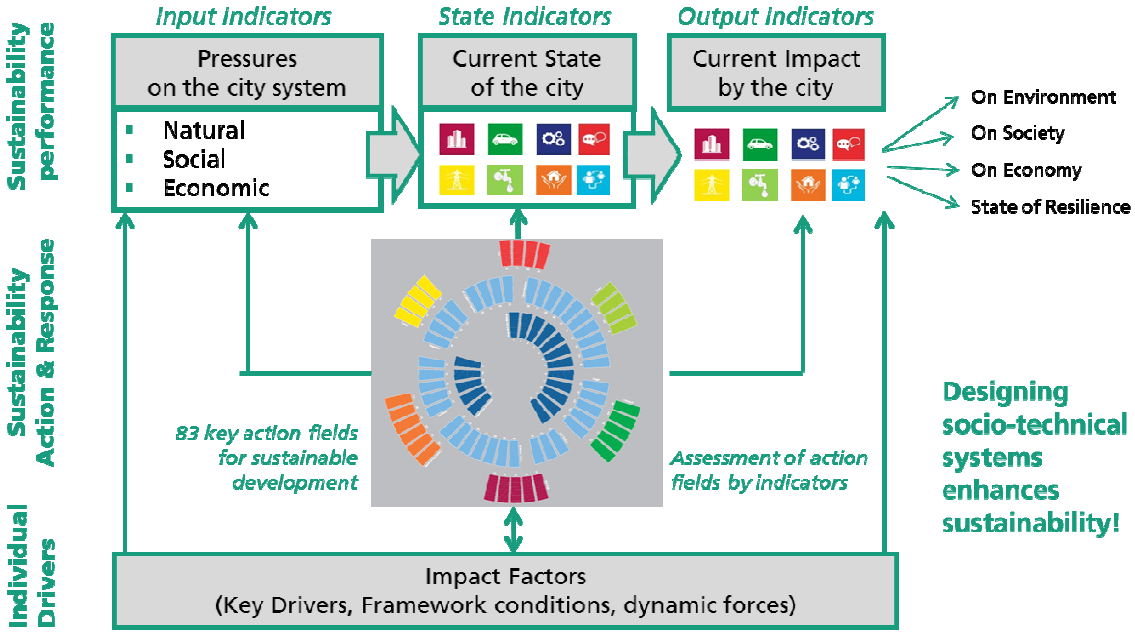

Figure 2: Morgenstadt model for sustainable urban development

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After the on-site research visitis, all prior defined indicators had been evaluated. The assessment showed that most variables are only available in some cities and therefore not usefull for general city comparisons. A revision of the m:ci indicators provided a set of less than 100 urban indicators that define the state of sustainability of a city. This indicators are listed in the final project report (Fraunhofer-Gesellschaft 2013).

The 83 defined key action fields for sustainable development represent the core of the Morgenstadt model. This action fields describe the sustainable actions and responses of the cities. They can be related to indicators and allow the m:ci researchers to assess whether a response of a city is in line with existing pressures or state conditions and therefore really helps optimizing outputs for enhanced sustainability. The key action fields were further assessed by the participating researchers. They rated the impact of each key action field to each other based on their field of expertise. This so called cross-impact matrix of key action fields was subsequently evaluated by the sum of active and passive ratings. By plotting the sums of each key action field, three groups of action fields could be seperated that have a significant relevance for sustainable development of a city (see Figure 3).

- The “drivers” were key action fields that bring ideas and initiatives forward.
- The “enabler” enables the city to perform certain actions.
- The “levers” amplify given actions.

The cross impact of each key action field to each other is also dynamicly visualized and accessible through the project website.

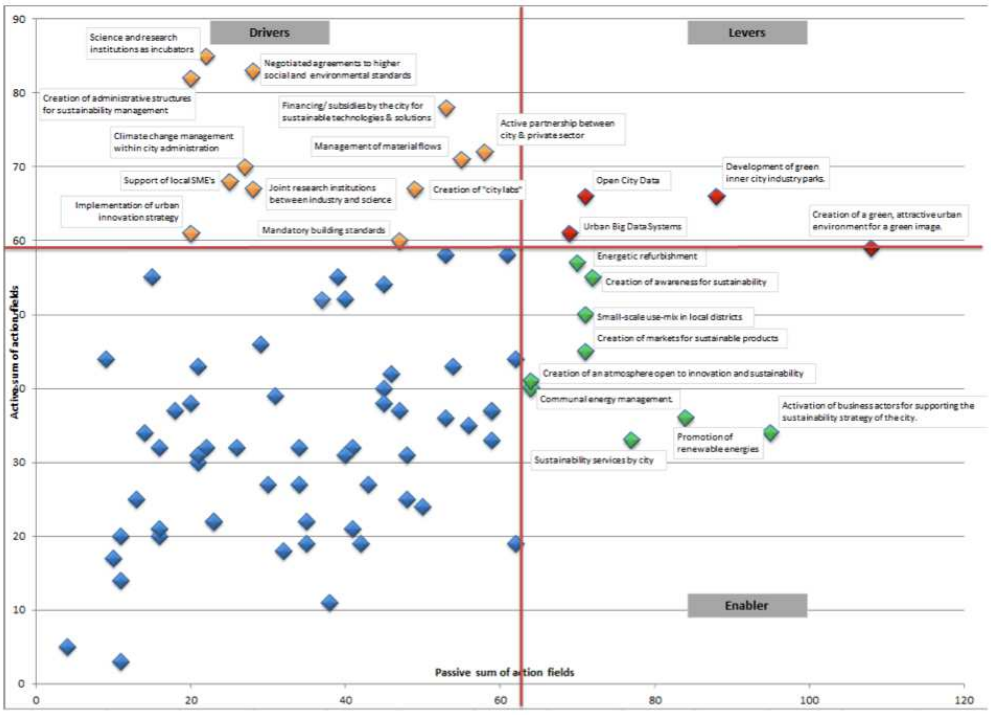

Figure 3: Cross-impact analysis of key action fields

3 THE ROLE OF ICT IN THE SMART CITY (OF TOMORROW)

In this context, the following chapter will concentrate on the ICT sector and its role for the sustainable and smart development of cities. Therefore the argumentation will follow the m:ci methodology, first providing an overview of the analysed best practices and subsequently deriving consitent impact factors as well as coherencies. Finally four key action fields and one central key insight for the ICT sector will be presented, including a discussion regarding the transferability of such solutions.

3.1 ICT best practices

As Table 1 lines out, the m:ci project analysed thirteen ICT best practices in four different cities. It can be stated that the thematic scope of those thirteen projects was extraordinarily broad. Thus the themes range from traffic management or ICT assisted security approaches to ICT tools for public participation. This

broad range is a first indication of the profound relevance of ICT solutions for the smart and sustainable development of city systems and their subsystems. On this basis chapter 3.2.2 provides a more detailed insight into the influence of the ICT sector vis-à-vis other sectors, such as mobility, water infrastructure, production and logistics, governance, buildings, energy and security.

Best practice	**Description**
New York, United States of America	
Open Data Initiative*	Urban data analysis for evidence based city planning and management
Smart Public Safety*	ICT assisted security (trend analysis and hot spot projection)
Berlin, Germany	
Capital Cloud	Open data approach (cloud networking for regional companies)
infreSt	Open data approach (pipeline network information)
Open-Data-Plattform*	Open data approach for community information and services
Verkehrsinformationszentrale*	ICT assisted traffic management
Vernetzte Sicherheit*	ICT assisted security
Smart Grids und Smart Metering Berlin-Brandenburg*	ICT assisted energy grid management
Tokyo, Japan	
Mobile Spatial Statistics*	Mobile data analysis to understand citizen's movement patterns (field of application e.g. urban planning and crisis management)
Interoperable Electronic Ticketing*	ICT assisted ticketing system for public transportation
Freiburg im Breisgau, Germany	
GRID2Smart*	ICT assisted energy grid management
Beteiligungshaushalt	ICT assisted participation platform for city budgeting
Baulückenbörse	Open data platform to manage the gap site market

Table 1: Analysed ICT best practices

All projects marked with an asterisk within Table 1 are based on one main idea: the smart use of already existing urban data. Moreover, the remaining four projects are basically providing new types of digital data, by collecting information and making it available digitally. Summarizing, innovative ICT solutions try to make cities smart by using and providing city data in a new, creative and analytical manner.

3.2 Results of the ICT sector

In the next sections the results of the ICT sector are outlined. First the identified impact factors are described. Then it will be discussed how ICT can be an enabler for sustainable and smart development of other sectors. Finally, key action fields and key insights are presented.

3.2.1 Impact factors

As explained earlier, the m:ci project tried to identify consistent impact factors within all best practices. With the help of detected success factors it should be possible to increase the chances of success for upcoming innovative project ideas. All analysed ICT projects revealed specific impact factors corresponding to local political, social and economic circumstances. Nevertheless, several impact factors were identified as substantial for numerous best practices.

The impact factor "existing networks of innovative actors" has been relevant in six of the best practices projects (out of 13) and is therefore the most important factor for the ICT sector. Cooperation between research institutes and other actors was an impact factor for three of these projects. However, other projects like the Open Data Initiative of New York also includes universities or research institutes as project partners, without depending on those networks upfront.

The political will of the city government to implement innovative ICT strategies and techniques was designated as an impact factor for 5 of the 13 ICT best practices. Among other things, this factor is of great importance, because the financial support of ICT projects depends on political decisions. Additionally,

financial funding respectively funding programs were named as central impact factors for three of the ICT best practices. Accordingly, a municipality that wants to support a smart city approach should be dedicated to technological innovations and should support and initiate networks of innovative actors of the ICT sector.

On the other side, looking at obstructive impact factors, the intensive use of digital data depends strongly on legal regulations and the societal awareness regarding privacy issues. Especially during the last years the public awareness raised due to massive data collection of companies and organizations. Cities that want to use personal data of inhabitants need to communicate the dimension of the data collection and processing transparently, further clarifying the benefits for each citizen and the society as a whole.

3.2.2 ICT as an enabler for sustainable and smart development of other sectors

Since innovative ICT solutions support a broad spectrum of city related themes and projects, not one single ICT best practice project is limited exclusively to the ICT sector but connected to other sectors. Exemplary the Interoperable Electronic Ticketing project in Tokyo as well as the Verkehrsinformationszentrale in Berlin have to be considered as projects of the mobility sector, benefitting from a "smart" usage of data with the help of ICT. Moreover, the Smart Grid projects of Berlin or Freiburg im Breisgau could be assigned to the Energy sector, the Beteiligungshaushalt is also aiming at the governance sector and the projects Vernetzte Sicherheit and Smart Public Safety can be seen as parts of the security sector.

The level of impact of the ICT sector for other sectors is shown in Figure 4, which describes the dependences between all defined key action fields with those of the ICT sector (The more bars in the middle rings the higher is the relation). This figure, which is based on expert ratings, illustrates the extraordinary interdependencies between the sectors ICT and mobility as well as ICT and security. Nevertheless, it can be noted that all sectors are affected from ICT key action fields to a certain point.

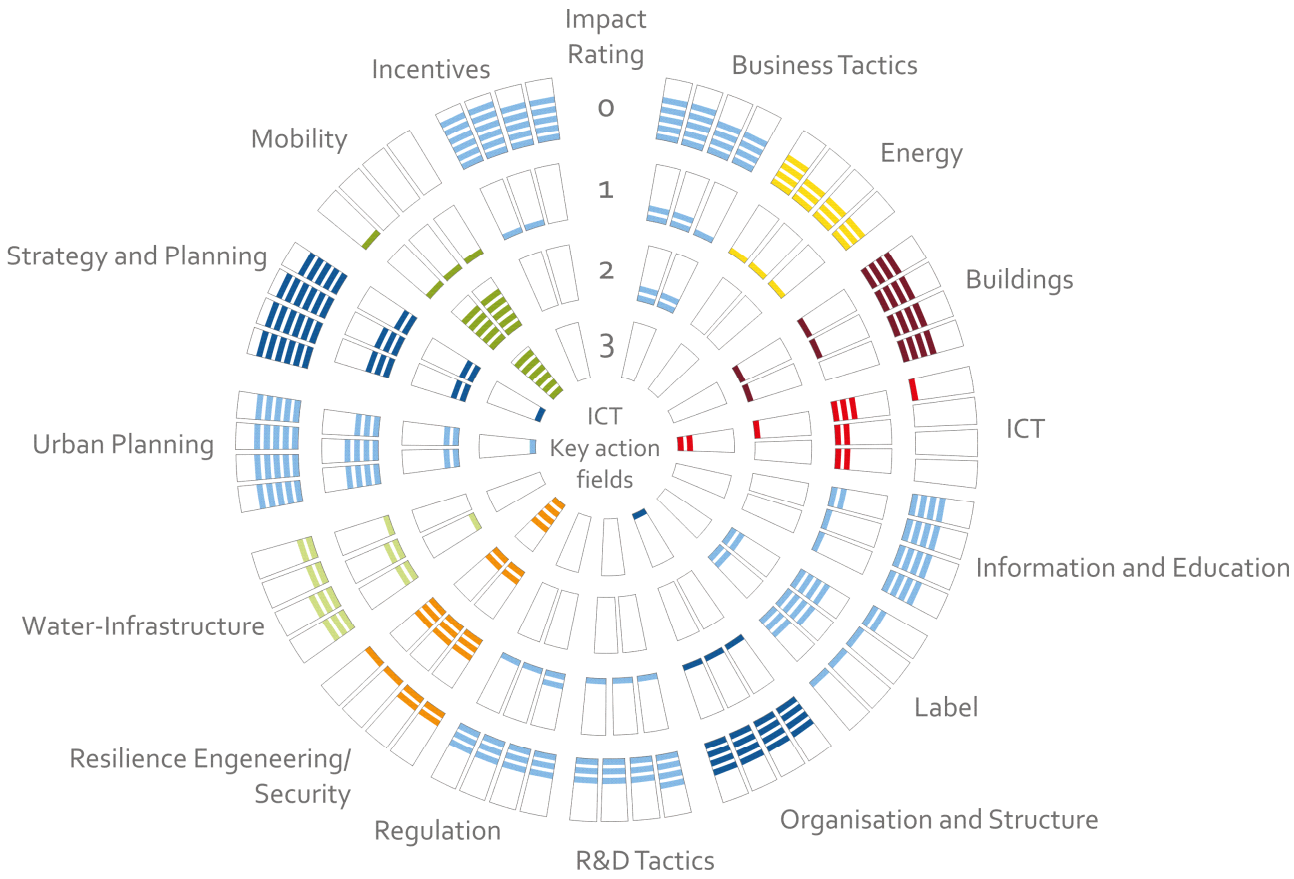

Figure 4: Impact of ICT key action fields

All these best practice projects used ICT in order to achieve one or several of the following three main goals:

Efficiency

Usually ICT solutions are implemented in order to optimize processes. This optimization includes approaches regarding higher efficiency, evidence based decision making, improved target group addressing and much more. Exemplary project: GRID2Smart in Freiburg im Breisgau.

Promising opportunities of technologies

In various cases ICT solutions were adopted because they allowed addressing existing problems with completely new approaches. In fact, sometimes they are able to uncover so far unknown problems and offer possible solutions to deal with them. Exemplary project: Open Data Initiative in New York.

Emerging demands

Moreover, the digitalization of cities includes societal changes too. Like Montgomery et. al. (2004) already discussed, new generations of digital citizens evolved during the past decades. These highly connected inhabitants demand for new products and solutions in order to organize and live their lives. Exemplary project: Interoperable Electronic Ticketing in Tokyo.

3.2.3 Key action fields

As also outlined in chapter 2.2, sector specific key action fields were identified during the city visits in order to highlight recent innovative developments which have proven positive impact on entire city systems. In this context, four key action fields can be named for the ICT sector.

Open Data Systems

The core idea is to provide municipal data for citizens and local companies in order to ensure transparency and enable inhabitants to control their authorities. This key action field consists of various best practices as for example the Open Data Platform and infreSt in Berlin or the Beteiligungshaushalt of Freiburg im Breisgau.

Urban Smart Data Systems

Such systems are applied in order to gather and process the increasing amount of emerging city data to optimize municipal processes and to provide a foundation for evidence-based decision making. Like the previous key action field, “Urban Smart Data Systems” combines different best practices, like the Open Data Initiative in New York or the implemented Smart Grid solutions in Freiburg im Breisgau and Berlin.

Intelligent traffic management based on real time information

A system of receiving units collects real time traffic data from the city’s streets. An operation terminal collects the information and calculates optimal traffic flows. The results are used for traffic management. Driver information is provided by real time street displays or directly to navigation devices. Related practice examples are the Verkehrsinformationszentrale in Berlin or Tokyo’s Vehicle Information Communication System (VICS) which was analysed by the mobility sector experts of the m:ci project, collaborating with ICT specialists.

Interoperable electronic ticketing systems in public transport

Optimally such an approach will be implemented with a single card or device that allows passengers to use all public transport vehicles (e.g. subways, buses or taxis) within a city. These systems have to meet the following three main criteria: (1) optimal usability for passengers, (2) interoperability within means of transport and operating transport companies and (3) cross-domain applicability (versatile payment methods in the city).

The four presented key action fields have not only shown their positive impact for the analysed best practice projects and cities, rather they represent the central four ICT key approaches that should be considered by cities all over the world in order to become smart, sustainable and resilient. Other urban areas of the world already started to implement comparable approaches, as for example in Hong Kong or the Netherlands, were chip cards exist that cover various means of transport from local ferries up to regional trains.

Additionally, a fifth aspect has to be considered as a future ICT key action field, although first approaches are just beginning to develop. Digital self-helping structures for the society will become more and more important worldwide within the next years. This development was, among others, observable during the last few years in the context of natural disasters. National and global non-profit organizations are trying to involve citizens in data collection processes during natural catastrophes with the help of smart phone applications (Meier 2013). Citizens are also initiating and organizing their engagement on social media platforms, as occurred, for example, during the 2013 flood in the German city of Dresden (Ulbig 2013). With the help of social media platforms (e.g. Facebook and Twitter) that are deeply grounded within societies,

inhabitants get the chance to be proactive regarding all kinds of social, economic, environmental hazards. Cities should engage citizens to strengthen the resilience of local communities and to foster their sustainable development with the help of such self-organized smart community solutions.

3.2.4 Key insight

It can be concluded that a wide provision of urban data and their intelligent use can enable cities to achieve a smart and sustainable development. Nine out of thirteen ICT-oriented best practice projects were based on the same main idea of knowledge acquisition through use of urban data. Further, the four remaining projects are producing data sets that could also be consulted for such projects. The previously named ICT key action fields correspond to this outcome, concentrating on the use and provision of digital city data for all fields of application. With this background, one ICT key insight can be derived: the intelligent use of data in urban systems.

Cities can use existing or new (with the help of new sensor systems) data sets in order to optimize municipal processes and take evidence-based decisions. Cities that apply data analysis processes are able to get deeper insights into the living conditions of inhabitants. They are capable to identify emerging problems faster and will be empowered to cope with them independently. Such cities could be efficient working holistic systems that are connected via data streams of all kinds of application fields.

3.3 Transferability

In general, the transferability of the presented ICT solutions is not limited to specific external circumstances as for example geographic or demographic characteristics. Nevertheless, the transferability is dependent on the presented impact factors such as the political will, legal regulations and the societal acceptance.

With a view to the presented findings, one question regarding the transferability remains: What steps and measures are necessary to implement comparable solutions within a city? Concerning this, the following main tasks have to be adressed.

- Identifying relevant data sets respecting the intended field of application and privacy considerations.
- Collecting data automatically as well as developing and implementing of sensor systems.
- Analysing smart data with high performance analysis tools, including the development of additional tools in order to make data operational.
- Defining knowledge processes in order to base specific decisions on obtained results.
- Designing dissemination processes for public information.

In order to accomplish these complex tasks, cities will need help from different partners. Therefore research institutions as well as industrial partners could offer know-how (e.g. big data analysis) and technologies (e.g. sensors). Further, long-term collaborations between these actors should be established in order to act on the basis of a common strategy and to achieve optimal results. Jointly developed local ICT strategies are the first important step to integrate innovative ICT solutions within city projects and processes and to promote a sustainable smart city development in all fields of application.

Moreover, the second period of the m:ci project (2014-15) concentrates as initially intended on the implementation of successful approaches and solutions for other cities. In this context, city partners as well as industrial partners are working together with Fraunhofer experts to adapt identified promising solutions to the specific needs of the partner cities.

4 CONCLUSION

The substantial insights that were generated with m:ci illustrate the value of the project and the developed method. The interdisciplinary approach revealed a profound understanding for best practices and their impact factors, allowing the researches to identify yet hidden connections and commonalities between projects of all sectors.

Regarding the ICT sector the m:ci project has shown that:

(1) Innovative ICT solutions are able to support the sustainable and smart development of urban systems and all their sub-systems/sectors, and

(2) The smart use of already existing digital city data is a powerfull as well as realizable first step in order to make a city smart, sustainable and resilient.

In order to exploit the full potential of the presented ICT solutions and to make a city innovative and smart, cities should establish collaborations with local research instutions as well as to partners of the private sector. Nevertheless, cities need to meet their responsibilty towards the society by applying transparent processes, both during the implementation phase as well as while using urban data for specific purposes.

5 REFERENCES

BOJER, M.; ROEHL, H.; KNUTH, M.; MAGNER, C.: Mapping Dialogue. Essential Tools for Social Change. Ohio, Taos Publishing, 2008.

FRAUNHOFER-GESELLSCHAFT: Morgenstadt: City Insights Final Report. München, 2013.

KALISCH, D.; SCHATZINGER, S.; BRAUN, S.; RADECKI, A.: Morgenstadt: CityInsights. A Research Approach for Systems Research in Urban Development. In: Proceedings REAL CORP 2013 Tagungsband, pp. 571-578. Vienna, 2013.

MEIER, P.: MicroMappers: Microtasking for Disaster Response. Stanford, 2013.

MONTGOMERY, K.; GOTTLIEB-ROBLES, B.; LARSON, G.O.: Youth as E-Citizens: Engaging the Digital Generation. Washington, 2009.

ROEHL, H.; WINKLER, B.; EPPLER, M; FRÖHLICH, C. (Ed.): Werkzeuge des Wandels. Die 30 wirksamsten Tools des Change-Managements. Stuttgart, Schäffer-Poeschel, 2012.

ULBIG, M.: Anpacken 2.0. In: Sachsische Zeitung, 21.06.2013. Dresden, 2009.

UNITED NATIONS: World Urbanization Prospects The 2011 Revision. New York, 2012.

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