

# Implementation of Business Processes in Smart Cities Technology

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**Abstract.** The goal of the paper is to present the results of studies concerning the development of a method of implementation of business processes in Smart Cities systems. The method has been developed during studies carried out within the building of a Smart Cities system for Gdańsk, and is based on basic development project management mechanisms (drawing from best practices, and in particular from the RUP methodology) and business-oriented development principles, where the role of business process modeling is crucial for the implementation of functionalities of IT systems.

**Keywords:** Smart cities · Business process modelling · Decision support systems · Knowledge management

## 1 Introduction

The progress in smart information technology implies growing market interest in systems conforming to the so-called smart cities concept. Large urban agglomerations such as London, Singapore or Rio de Janeiro use IT systems to manage key processes in the city, such as road traffic management, decision-making for strategic projects or ensuring safety for residents.

Such an approach allows an urban agglomeration to be treated as an organization, in which a number of business processes occur, and these processes require the support of IT systems. A business process is usually defined as a set of operations which lead to the accomplishment of a specific goal or fulfilment of a specific business need [2]. The processes which have strategic significance for a city usually come from legislation, which provides the legal foundation for the processes carried out by a city. Among such processes, particular attention (and consequently special IT support) is attached to processes crucial for the safety and wellbeing of residents. Typically, certain procedures and guidelines which require immediate measures to be taken and the simultaneous absorbing of resources subordinate to key public order enforcement agencies such as police, fire brigade or healthcare are connected with such processes.

Key IT system providers strive to deliver software (“smart cities” systems) which supports the management of certain processes in urban agglomerations and their subsidiary units, such as crisis management centres. It should be noted that a crisis management centre is not an ad hoc organization, but an organization which constantly monitors certain (critical) statuses. This organization’s activity intensifies when critical values defined for KPIs (Key Performance Indicators) [1] assigned to specific processes are exceeded. Also, “smart cities” systems are designed not only to support decision-making in a critical situation, but also to constantly support the control and monitoring of certain aspects of life in urban agglomerations. As an example of a status which may be monitored and which requires a response by a crisis management centre we may include the concentration level of pollutants in the air, the water level in a river, the noise level for a given location, etc.

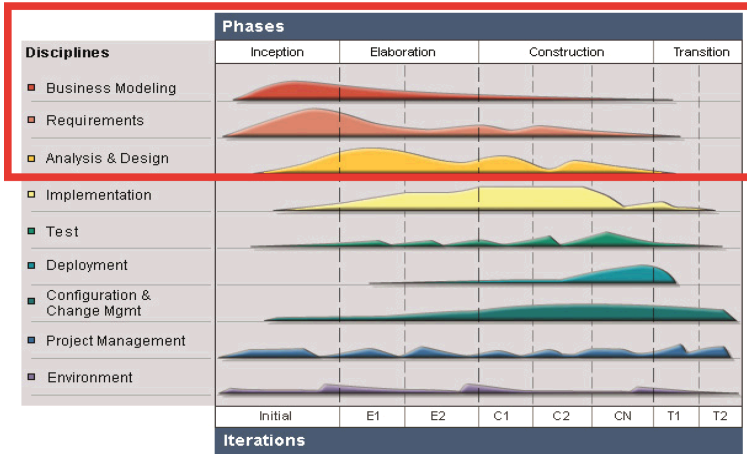
Hence this paper aims to show how the modeling of processes is relevant for their subsequent implementation in the form of specific functionalities of smart cities systems. To that end, the current methodology knowledge supporting aspects of business modeling and architecture modeling for the purpose of IT systems has been presented. Next, the recommended model of steps leading to the implementation in smart cities systems of specific business processes carried out by the city council has been presented.

Such an approach allows the implementation and deployment of smart cities systems to be perceived from the perspective of an IT project [5], in which the implementation of system functionality is preceded by a number of activities in the area of business analysis and modeling [6]. This in turn allows a city (city council) to be treated as the client of an IT project, who has specific expectations (business needs) which should be satisfied by the functionalities of the developed smart cities system.

## 2 Business Modeling Issues in the Development of IT Systems

Business modeling [4, 6] is one of the main disciplines of software engineering, and is particularly emphasized in such development approaches as Rational Unified Process (RUP), but is also relevant for currently popular agile approaches [12, 13] (Fig. 1).

The disciplines in the area of business modeling (RUP includes process modeling, requirement management and architecture modeling in these disciplines) serve to analyze in detail the business needs, and consequently the business processes occurring in the organization of the client of the IT project [7], i.e. the recipient of the IT system. Business modeling as a discipline refers first of all to increasing the abstraction level of a developed system through, inter alia, the graphical presentation of processes (process modeling) and also the graphical presentation of system functionalities (use-cases diagrams). Thanks to business modeling the communication between the client and the development team is improved. Business analysts, who through their contacts with the client visualize the processes and IT system’s functionalities required for subsequent implementation, are usually in charge of the business modeling.



**Fig. 1.** Scope of business process modelling in RUP

### 3 Business Modeling in the Development of Smart Cities Systems

As noted in the introduction, each implementation of smart cities systems is a particular case of an IT project, which means that the disciplines connected with business modeling (business process modeling) are applicable also in the development and implementation of such systems. The application of business modeling for the purpose of smart cities systems has two main advantages.

Firstly, it allows better understanding of the functioning of the client's organization and their business needs, so that the developed/implemented IT system is properly tailored to the business processes occurring at the client. In the case of smart cities systems such an approach seems especially important. The business processes of a client like the city council are very often connected with the safety of a significant number of residents, and ensuring appropriate living conditions and standard of living. The better these processes are understood, the more likely it is that they will be properly supported by the developed smart cities system.

The second advantage of business modeling is the improved collaboration between the client and the development team (the team which develops/implements) through creating a joint platform of communication based on models and the visualization of individual items (functionalities) of the system to be built.

Another advantage, which is more and more often expected from the use of business modeling for the purpose of the implementation of IT systems is the opportunity to make the model independent from the implementation platform. This is particularly useful in the current circumstances where technical debt (a phenomenon consisting of the lack of opportunity to develop or adapt the software after some period of operation) is becoming a serious threat. Technical debt also means the risk of being unable to develop or adjust the software to the changing environment (for instance, the integration of systems in the

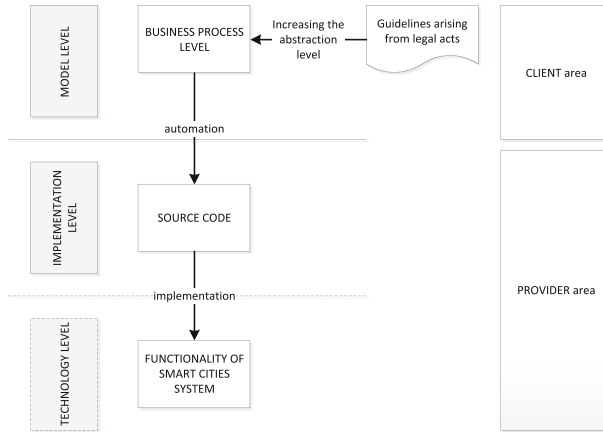
case of two organizations merging, or system modification(s) arising from legal requirements). The application of business modeling and the representation of an individual system's tasks through business process models gives an opportunity to minimize the risk of technical debt occurring, provided that appropriate conditions for the automatic implementation of processes in the IT system are created. Therefore the use of high-level business modeling should lead to a situation where any modification required to be implemented takes place only at the model (business process model and/or system architecture) level.

#### **4 Advantages of Business Modeling for the Purpose of Smart Cities Systems**

The increased abstraction level and the application of high-level models in the construction and implementation of smart cities systems brings about certain problems, however. As noted in the introduction, one of the main problems arising from the implementation of smart cities systems in cities is the need to tailor such a system to a specific city in each case. This is due to the fact that each city is governed by individual specific formal and legal principles. In addition, each city has a number of imposed guidelines, which govern its operation in a crisis situation (these are local procedures in the case of an accident being a threat to residents).

Due to such situations, when developing and implementing a smart cities system for a particular city, the providers have to seriously take into account that it is necessary to make adjustments with respect to specific procedures, guidelines, legal acts and other instruments of a formal and legal nature. Another factor, which makes it necessary to tailor a smart cities system to the city (client) may be the specific microclimate or geographic location, which makes it necessary to modify the system's functionalities depending on the location of a particular city. Therefore, in order to avoid implementing functionalities dependent on various factors in each individual case, smart cities system providers should strive to apply appropriate components, developed, if possible, at a higher abstraction level than the source code, i.e. at the business process model level. Hence the role of business modeling leading to the presentation of individual guidelines or procedures valid in a city in the form of process models, which may be later implemented in smart cities systems, becomes reasonable.

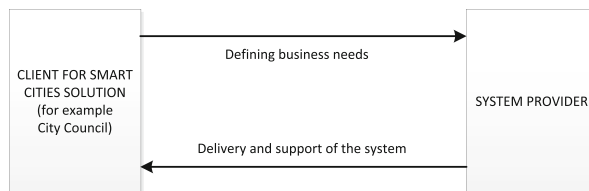
The above consideration allows the conclusion that in the application of business modeling for the purpose of smart cities systems, reusable components should tend to be provided. Such components, due to their relative independence from the system proper, should allow unrestricted implementation based on procedures and guidelines delivered or held by the client (the city). Therefore in the next section particular attention is attached to a procedure model leading to the implementation of business processes defined in formal and legal documents held by the city council (Fig. 2).



**Fig. 2.** Role of business modelling in the implementation of smart cities systems

## 5 Model of the Implementation of Business Processes in Smart Cities Systems

In connection with the above consideration it should be said that the implementation of business processes in smart cities systems should be preceded by some business modeling activities. It seems appropriate for software providers, when implementing smart cities systems, to take into account a number of key aspects mentioned above, such as the necessity to increase the system's abstraction level through the visualization of processes and functionalities. Hence the main mechanism leading to the realization of business modeling principles [11] is the defining by the client of the needs which have to be reflected (satisfied) in the smart cities system (Fig. 3).



**Fig. 3.** Collaboration loop for smart cities solutions

The client's business need may be perceived both as a specific service provided by a smart cities system and as a specific task, which may be supported by the system. However, in order to implement such a service it is necessary to model it properly, and

the best option here is modeling in the form of specific business processes with use of a certain modeling standard such as BPMN or UML [3, 14]. It is true that business processes in the case of city councils are quite different from business processes for a manufacturing company or a typical commercial organization. However, a city's activities have obviously a process-related character and may, or even should, be presented in the form of diagrams (process models) in order to facilitate their implementation in smart cities systems.

A particular problem noticed in the case of a number of city councils is that procedures and guidelines which should be implemented in smart cities systems are usually only described in the documentation (expressed in natural language). This means that those responsible for modeling have to devote some effort in order to convert descriptions in natural language into business process models. Only when this conversion has been effected, can these processes be implemented in smart cities systems. Hence before implementing business processes in smart cities systems it is necessary to analyze in detail (such analysis is mainly carried out by analysts in collaboration with city council employees) relevant procedures and guidelines in order to model them as process maps.

### **5.1 Issues Connected with the Implementation of Procedures and Guidelines in Smart Cities Systems**

The main problem potentially encountered during business modeling for the purpose of smart cities systems is the non-typical character of business processes. In city management the processes which should be implemented in a smart cities system are different from typical development processes. In city management, the activities (processes) connected for example with responding to an exceeded critical threshold for the air or water, consist of taking the appropriate measures directly with regard to guidelines in relevant legal acts (which is shown in the corresponding diagram above). Hence the question may be asked whether business process modeling may be applicable at all for an organization like a city council.

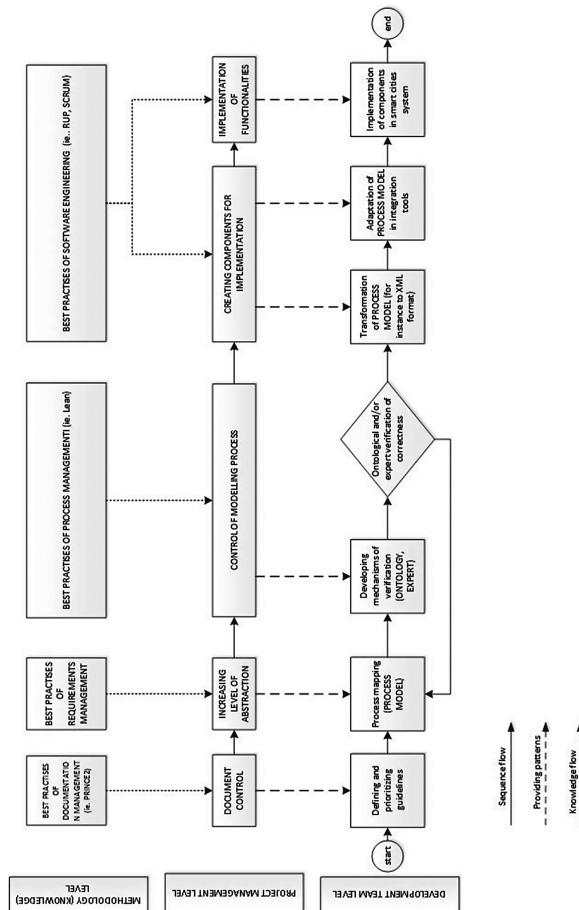
It might seem that such modeling will be a redundancy of the knowledge which has already been entered in the form of entries in dedicated regulations. However, one should keep in mind that business modeling is to serve as a bridge between the development team and the client (city council). Therefore in this situation process modeling should be regarded as a platform enabling better communication between individual project stakeholders [9].

On the other hand, the modeling of processes for the purpose of their implementation in smart cities systems is connected with another problem arising from the formalization of such processes. If business modeling is treated as an important factor for the development of reusable components, it becomes necessary to apply certain standards for the modeling of such processes. BPMN may be mentioned as one among the most commonly applied standards today for modeling such processes; however, although users are increasingly familiar with this standard in provider organizations, this is not always the case in organizations on the part of the client.

However, the necessity to model business processes for the purpose of a city council seems to be inevitable and falls into the category of typical “business-oriented software development” principles [6], which are not only emphasized in individual IT project management methodologies, but are slowly becoming a standard in the realization of development processes. In response to these issues, a procedure model connected with the implementation of business processes for the purpose of cities which use (buy/ implement) smart cities systems has been presented below.

## 5.2 General Model of the Implementation of Business Processes in Smart Cities Systems

As noted above, the main problem connected with business process modeling for the purpose of smart cities systems is the necessity to carry out a multi-aspect (multi-thread) business analysis. On one hand, those responsible for modeling deal with the



**Fig. 4.** General model of the business processes in smart cities systems

documentation (legal acts, standards, regulations), which must be reflected in the system. On the other hand, good software engineering practices make it necessary to present these aspects contained in the legal acts at a sufficiently high level of abstraction. Thus it means that when intending to model business processes and implement them for the purpose of smart cities systems, at least three organizational levels should be taken into account, which influence the realization of modeling and implementation activities.

The first, and the highest level, is connected with best practices of procedure — both for documentation management and best development practices. This level may be called the knowledge level and it is designed to ensure methodological best practices of procedure. However, it should be kept in mind that the implementation of smart cities systems is a typical IT project, and thus a number of activities have to be carried out in accordance with project principles (managing, control, monitoring progress) at the operation level (project management). And finally, at the lowest level, individual activities are carried out which enable the creation of process models and their implementation in smart cities systems. Such an approach is in accordance with hierarchical project management represented for example by PMBoK or PRINCE2 [9, 10].

These three key levels are reflected in the model shown in Fig. 4.

As noted above, the procedure model for the purpose of the implementation of business processes in smart cities systems takes into account three main levels, which are interrelated. Each of these levels is a certain organizational level. Such an approach makes it easier for the persons modeling business processes to analyse the knowledge sources supporting specific activities (knowledge level) in the modeling area, and also indicates the activities (project level), which should be effected during the development of smart cities systems.

- **METHODOLOGY (KNOWLEDGE) LEVEL** is the highest layer of the model of the implementation of business processes; this layer is to provide appropriate knowledge required in order to carry out modeling and implementation processes. Hence the presence of this layer in the model gives the modeling persons and implementing persons insight into necessary sources of substantive knowledge used in the management of development projects. This layer is aimed at ensuring, inter alia, best practices applied in IT projects, with a recommendation to make use of approaches such as PRINCE2 (for instance for documentation management), RUP (increasing the abstraction level), LEAN (improving what was already created).
- The second level of the model is the **PROJECT MANAGEMENT LEVEL**, i.e. the realization of particular organizational activities aimed at the delivery of the system's functionalities. The best practices from the higher level provide knowledge for this management level, for which the project manager and/or the steering committee is in charge. This level is aimed at the delivery of procedure patterns to be applied by the development team creating smart cities solutions. The patterns, which are supplied from the management level, have been divided into the following: document control (i.e. the gathering and processing of legal acts, regulations and other sources, from which the guidelines are derived), the provision of patterns to increase the abstraction level (for instance BPMN, UML notations) and also the provision of patterns for control, for example tools (in accordance with the **TOOLS & TECHNIQUES** principle) for the verification of developed models. Finally, at the management

level attention should be paid to design patterns (in RUP these is called capability patterns), i.e. a recommendation to apply reusable components, which later may be implemented autonomously in subsequent systems. Thus, the last set of management activities is the realization of the implementation processes, reflecting the development level.

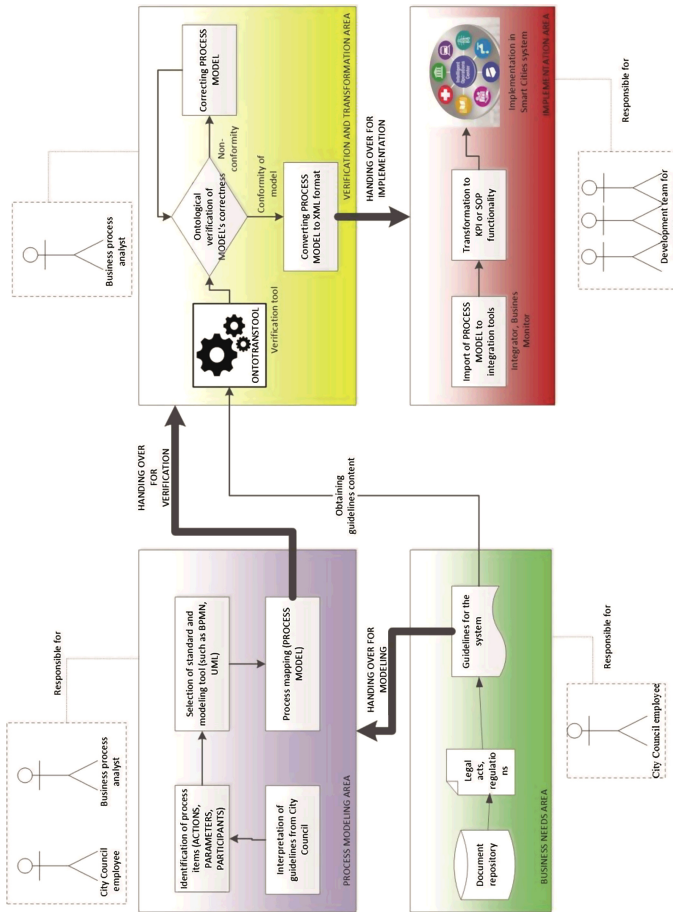
- **DEVELOPMENT TEAM LEVEL**, i.e. the model level dedicated to the development team in order to deliver some procedures of operation (autonomously developed by the authors and discussed in detail in a further section). At this level, firstly one should refer to the interpretation of guidelines, which are to be modeled in the form of a business process, which subsequently should be verified (the team has developed a dedicated tool for verifying the conformity of the process map/model with the documentation on the basis of ontologies). Next, when the process model is in accordance with the guidelines (documentation), it may be converted into an interpretable form by means of dedicated tools applied for the development of smart cities systems. Due to the high degree of complexity of this level, it has been further extended as a detailed model.

### 5.3 Detailed Model of the Implementation of Business Processes

The developed general model indicates the main layers which are required in order to carry out correctly the business modeling for the purpose of the implementation of smart cities systems. In addition, the modeling persons (business analysts, city council employees) should take into account a number of additional activities (recommended by the authors of this paper) enabling the correct modeling of procedures and guidelines, which may be later implemented in smart cities systems. Hence the detailed model considers the actors (participants) in individual activities carried out for the purpose of the implementation of business processes in smart cities systems, presents the sequence of activities, and also shows the processes which are of key significance for the modeling, occurring within such areas as defining business needs, process modeling, the verification and control of correctness, and implementation (Fig. 5).

The detailed concept of the model also contains, apart from the main areas connected with process modeling and implementation, responsibility for individual activities leading to the implementation of processes in smart cities systems. Hence a relevant city council employee is responsible for providing documents with procedures and guidelines necessary for the subsequent modeling of business processes, which will be implemented in the smart cities system. It should be noted that although the guidelines come from legal acts (like charters, regulations) held by the city council, it is the particular employee who defines their business need (i.e. which items the system should contain so that employees are able to fulfil their duties arising from the legal acts).

When the guidelines have been prepared, the business process modeling stage takes place. A process analyst (who may be indicated by the city council or may come from the provider's organization) through consultation/collaboration with the city council employee begins the business process modeling. In a mature organization, processes would be modeled by department employees, while in a less mature organization competent consultants should also be involved. In the process modeling area indicated



**Fig. 5.** Detailed model of the business processes in smart cities systems

in the model, in the beginning, the relevant guidelines in the documentation provided by city council employees are interpreted. The interpretation is a process strictly connected with activities such as the analysis of the content of an act/ordinance, on the basis of which the subsequent system functionalities are to be created. Next, all the elements within the process, namely the entities (process participants), the actions taken by the entities (process activities) and the conditions (process parameters) such as permissible pollution concentration levels, etc. are identified (through an analysis of the text). When all the elements within the process have been determined, the appropriate modeling standard should be selected. A certain standard is necessary in order to avoid disputes as to workflow within the process (hence the present standards such as BPMN or UML are recommended). After having selected the modeling standard (notation) and modeling tool (in accordance with best project management practices [9]), process mapping can proceed, i.e. a graphical presentation of the process within the tool.

Another area in which the tasks required for the implementation of business processes in smart cities systems are carried out, is the verification of the previously developed business process model. In this paper a verification based on ontologies [8] (based on the experience of the authors) is recommended. In the studies carried out by the authors, mechanisms have been developed of automatic verification of business process models on the basis of linguistic descriptions based on the dedicated ONTO-TRANSTOOL tool. This tool, on the basis of a description in natural language, identifies all entities, i.e. process elements contained in legal acts/ordinances, and then it is checked whether the processes modeled and generated by ontologies are convergent with those modeled by the analyst on the basis of contacts with a representative of the city council. This control is carried out expertly by the analyst. Should any discrepancy be found, the process will be remodeled.

After having verified the process model the export file should be prepared (based for example on XML standard) for the subsequent importing thereof by dedicated tools integrating processes with smart cities systems, such as IOC. Therefore the last area of the procedure model is connected with the integration and implementation of already modeled business processes in the smart cities system. By means of a dedicated tool one can import the process model written in xml format, and then send the model imported from the integration tool to the person in charge of the implementation of business models in the smart cities system (in the case of IOC it is the appropriate INTEGRATOR and BUSINESS MONITOR). Only after having imported in the BUSINESS MONITOR is it possible to generate the desired functionalities corresponding to the needs from the BUSINESS NEEDS AREA, such as Key Performance Indicators (KPIs) or Standard Operating Procedures (SOP).

## **6 Verification of the Model of the Implementation of Business Processes in IBM IOC**

In this section an example concerning a threat arising from exceeded PM10 concentration in the air for the Tri-City agglomeration, the city of Gdańsk, Poland has been used, on the basis of the guidelines provided by Gdańsk City Council, as an example to illustrate the opportunities for the implementation of business processes in smart cities systems. In connection with the prior considerations it should be noted that in the case of urban agglomerations most activities showing symptoms of a business process arise from guidelines and procedures being formal and legal constraints for the decision makers and users of smart cities systems. This section aims to present how to automate the implementation of guidelines, which are represented in the form of a business process model, within smart cities systems.

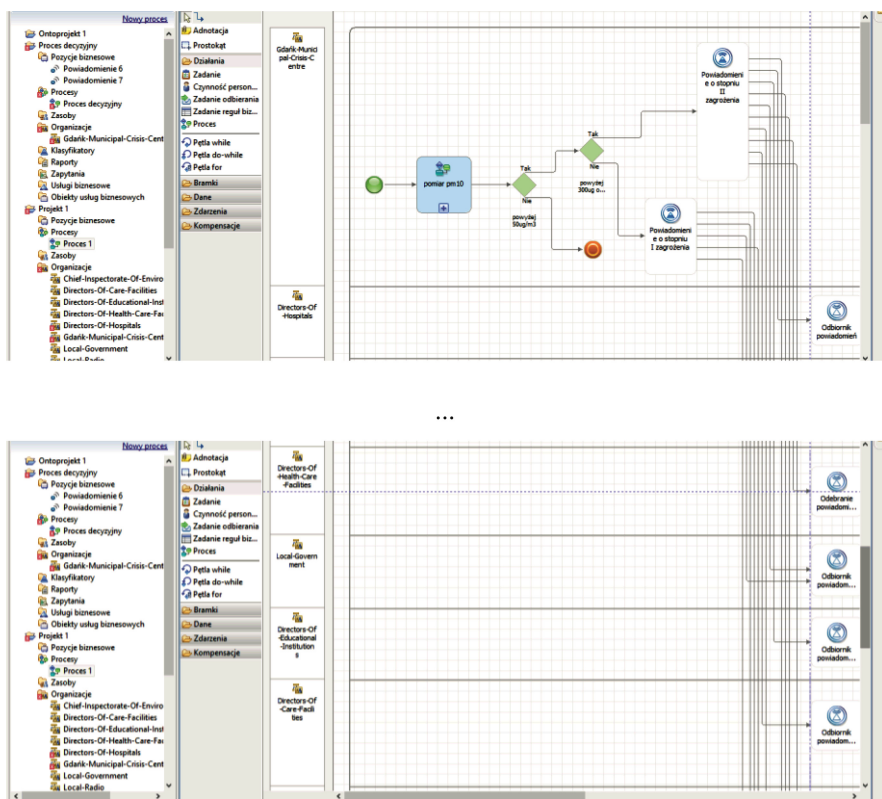
**EXAMPLE.** During the work carried out for the purpose of the implementation of such a system for the city of Gdańsk, a procedure was used describing certain measures to be taken in a situation where one of two thresholds for PM10 concentration is exceeded. When the lower threshold (in the analyzed case the threshold is  $50 \mu\text{g}/\text{m}^3$ ) is exceeded, it means the occurrence of the first threat level, and the action to be taken consists first

of all of notifying the appropriate units. When the second threshold ( $200 \mu\text{g}/\text{m}^3$ ) is exceeded, more units are notified and certain entities (such as the fire brigade) are alerted. The entities to be notified and alerted are specified in the relevant regulations.

As can be seen in the description above, the guidelines (procedure of conduct) include several main elements, which allow them to be treated as business processes. Each procedure (guidelines) is composed of the following elements:

- actions (measures to be taken by the smart cities system operator when a critical situation has occurred),
- parameters (critical values which stipulate defined measures to be taken),
- process participants (individual entities taking measures or notified after a critical situation  $x$  has occurred).

The persons who have been notified by the crisis management centre (i.e. the entity which manages the information flow) that a certain event has occurred, operate in accordance with their charter-based duties and in-house procedures. Within the studies carried out on the basis of the IBM IOC platform, the implementation of such processes may take place only through such tools which may be integrated with the IOC platform.



**Fig. 6.** Model of the process in WEBSPHERE MODELER

The IBM Websphere Modeler (Advanced version) is a tool dedicated for such purposes. During the studies the guidelines concerning an exceeded PM10 concentration level were modeled within this tool, in accordance with the process definition contained in the documentation provided by the city council. The model of the above mentioned procedure is shown in Fig. 6.

Next, the model developed within the tool is confronted with the process model generated by the ONTOTRANSTOOL tool in order to verify correctness. In the case of minor differences the modeling person could correct the already modeled process, if necessary. At this stage of the studies, the checking of the conformity of the process modeled by the analyst with the one generated automatically by the ontologies takes place manually. The differences which have been noticed during the verification of the developed procedure model for the implementation of processes could be for example attributed to the fact that in the documentation a group of entities may be indicated as a single participant in the project, while the tool based on the ontologies [8] treats these entities as independent items (for example the notified group comprises directors of schools and kindergartens). From the point of view of the person modeling the business process, this may be a single track of the process, and from the point of view of the ontology, directors of schools and kindergartens are separate items, and thus separate tracks in the process. This does not influence the subsequent implementation of functionalities (both entities will be notified about a threat as defined in the relevant procedure), however, the suggestion to specify accurately the recipients of the information may serve as a hint for persons who define procedures in the city council.

## 7 Summary and Recommendations

The goal of the above consideration was to indicate the role of business modeling in the development of smart cities systems. The developed procedure model for the implementation of business processes indicates the key areas for managing documents with guidelines. On the basis of the guidelines it is recommended to develop a process model which will reflect the procedure of conduct (for example in a crisis situation) contained in the documentation. Next, it is recommended to verify the developed process model (the authors have applied a dedicated tool based on domain ontologies) for correctness with the formal and legal provisions in the documentation, and only afterwards to proceed with the actual implementation.

Such a solution enables the correct implementation of business processes, and consequently, the system functionalities would be better tailored to the users' (clients') expectations. Also, when we use the process model, any modifications are made to the model (and not in the code) and therefore the modifications are better understood by both the client and the development team.

The application of business modeling for the purpose of smart cities may be a response to the technical debt risk and may serve as a certain platform providing protection against a shift in technology. When we use a modeling standard (for example BPMN or UML) and later ensure a mechanism for the translation of the model in a specific standard into integration tools (which is recommended by the authors), it is very likely

that we will be protected against technical debt risk. Such an approach also means an opportunity to make better adjustments to any changes in the law and provides more opportunities to the software provider to reuse such previously created components (for example when in another city the procedure is similar, but criteria values are different).

Further work on the developed model should be directed towards full automation of the implementation of business processes, i.e. the transformation of the already modeled process to the source code. The bridge solutions applied by the authors require at least two additional tools — an integrator and a model management system. Full automation would allow independence from other technologies; this would speed up the implementation processes of the functionalities, and in the future might provide an opportunity for the autonomous management of the system's functionalities by the users (for example city council employees, who by modeling the process themselves ensure its realization in the smart cities system).

It also seems reasonable to strive to unify modeling standards, and, in the case of platforms such as the IBM IOC platform applied by the authors, a greater openness to process models created in other notations than those contained in the related tools would be welcome. Thanks to that there is a chance that the recipients (cities) that have already modeled their processes in the BPMN standard will not have to transfer them to the modeler's own notation.

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