The use of modelling tools for modelling of spatial analysis to identify high-risk places in barrier-free environment

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***Abstract*—**During the preparation phase of project, significant decisions concerning data, analyses, software tools, visualisation methods, etc. must be made. Business processes modelling includes all these necessary activities. The contribution is focused on modelling processes of spatial analyses usable for identification of all kinds of problematic places from the point of view of the barrier-free approach. The reason is that making suitable models can increase level of understanding solved tasks. Many various means of expression can be used for modelling. Suitable diagrams belong to the most widespread modelling tools. In practice, diagrams used for business processes modelling or for information systems modelling (e.g. EPC, flow-chart, and others) belong to the most often used diagrams. Possible ways of utilization of the above stated diagrams for modelling spatial analyses are described in the text.

***Keywords*—**Process modelling, Diagrams, Spatial analyses, Barriers.

I. Introduction

VERY oten we encounter barriers in municipal environment. For a certain group of people, these barriers represent impassable obstacle to their day-to-day duties. Barrier free environment can serve as one of indicators of municipal infrastructure development level. Special facilities and special clients are developed in order to make movement of physically impaired people easier [1], [2]. Great attention is given to visually impaired people [3], [4]. The study addresses detection of barriers in bicycle routes, which are in a number of cases similar to barriers for physically impaired people. The preparation phase of project is often left out in course of spatial problems solutions. Spatial analyses modelling includes also such activities which need to be done before the analysis itself in the preparation phase, which is no less important, because data, analyses, software environment, visualization methods etc. are being determined. The text shows possible usage of process diagrams on examples; these diagrams could contribute to better understanding of the problem before the spatial analysis itself.

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II. Business Processes Modelling

A. Business Process

Currently, there are many definitions of the term process (see for example [5] – [8]), which differ by their point of view or origin date. Based on individual definitions, we can state that a process is an ordered set of steps or activities performed on a certain place in certain time. It has one or more inputs and it coverts these inputs to measurable outputs. Process outputs (usually product or service) have a single task – to fulfil requirements of either external or internal process customer. Processes should be compliant with strategic goals of the organization.

A process always consists of activities which are mutually interconnected. A process can also consist of individual functions – so-called sub-processes. Individual processes are triggered based on certain stimulants (reasons). Trigger to a process can be internal or external fact. External reasons for triggering a process originate from outer process environment. Internal trigger addresses rather individual activities. It is given by the situation, in which the activity is – its state. Individual activities are mutually connected and are described by relations. Process output and customer are important too. [5], [6]

Each process has characteristic attributes, which can be expressed by these elementary characteristics [5] – [9]:

- process is created by an ordered set of activities,
- it is necessary to choose route through activities,
- activities are performed by actors realizing certain work roles,
- actors work within certain organizational units,
- process has clearly determined start and end point,
- process is triggered by external or eventually internal event,
- process transforms inputs to outputs,
- process output represents value for internal or external customer,
- process performance can be measured based on process output,
- resources such as information, technology or tools are used,
- process output is not unique,
- process output is repeatable.

There are many types of processes; it depends on point of view. They can be classified by time prosperity – processes ensuring short term prosperity (i.e. production, product sale) and processes ensuring long term prosperity (research and development). Further, we can classify technological processes (i.e. production) and information processes (market research). Processes can also be divided by their relation to management level. In practice we often use division to processes [10]:

- business – help to fulfil organization missions,
- management – their task is to create unified and maximally efficient management system,
- support – provide products and services to customers or to key processes.

B. Business Process Models and Modelling

A model is a formalized system, which serves to illustrate the process studied. It allows illustrating and optimizing of process structure and to remove unnecessary processes. Simple graphical expression of the model is usually not enough, word description is usually attached in order to clarify and describe creation purpose and it describes the model as a whole. [11], [12]

Modelling is a tool for mapping real world with certain form of knowledge and laws working in it. Process modelling records all characteristic attributes of a process, most often by means of diagram [12].

It is possible to define several approaches to process modelling, which complement each other and are mutually interconnected, for instance [5], [8]:

- Behaviour specification approach – this approach is basic, because it has to describe first what will be modelled. It addresses setting of conditions and events which are necessary for performing individual activities.
- Structural approach – the main task is to identify entities and resources which enter process including attributes, activities and mutual relations.
- Functional – this concept addresses functions realized during the process.

Currently, there are many process models (business process models – BPM), for instance EPC, BPMN, selected diagrams such as UML, flow chart, value-added chain diagram etc. Whole BPM is usually created by a set of diagrams [6], [13] – [15]. Considering increasing significance of process modelling a need to measure quality of individual models emerged. That is why metrics which stem from object-oriented concept were designed [13].

As it was stated before, each process usually consists of individual functions (sub-processes). A process can be hierarchically decomposed to functions until the function still has a meaning from business sense; this means that it has meaningful output [8].

III. Methods and Languages for Process Modelling

In practice there are a number of standards, methods, tools on different levels of formalized languages which are suitable for modelling processes. Individual tools differ by extent and purpose. A number of them are influenced by information systems and technologies. In this article, following diagrams will be discussed:

- Use Case Diagram,
- Function Tree Model,
- IDEF0,
- Flow Chart Diagram,
- EPC Diagram.

There are a lot of kinds of software for process modelling (see Fig. 1, 2).

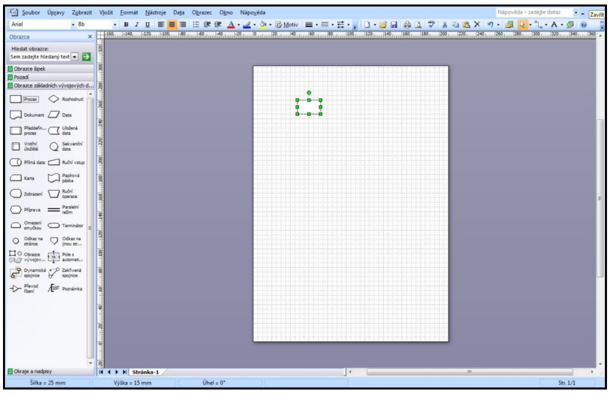

Fig. 1 – Interface of Microsft Office Visio 2007

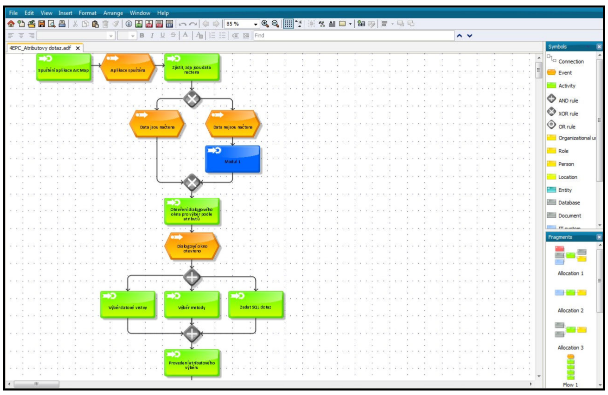

Fig. 2 – Interface of ARIS Express

A. Use Case

A Use Case is a tool for capturing functional requirements on future information system.

Use cases usually consist of diagram and scenario. Scenario captures sequence of activities including possible alternatives, which are consequently realized by system, so that actor gets a meaningful result or value. Diagrams of use cases belong to behavioural diagrams, which are part of UML standard. They are tools for graphical interpretation of relations between use cases and actors. Diagrams designed with use cases present users their requests better. A use case diagram contains these symbols: system boundary, actors, use cases, relationships. [16]

Advantages of use cases:

- process context is modelled – all participating objects and subjects,

- actors are emphasized,
- allow indication of main functional requirements of users on system, that means that they map activities within process,
- capture communication of actors with system.

Disadvantages of use cases:

- do not capture internal structure of the process,
- do not state how the system behaviour is implemented,
- there can be a misunderstanding if the scenario is not elaborated clearly,
- when a complex scenario is created, the process can be misunderstood.

B. Function Tree Model

Function tree model expresses relation between processes by means of tree structure. Root of the tree represents whole system. Each process is related to exactly one process of higher level; lower level processes could be bounded to a process. Tree leaves represent processes which could not be decomposed more (see Fig. 3). [15]

Advantages:

- definition of all processes within given process,
- decomposition of process activities to 3 groups of processes by their purpose,
- minimal number of symbols.

Disadvantages:

- it is not defined who participates in the process,
- sequence of processes is not clear.

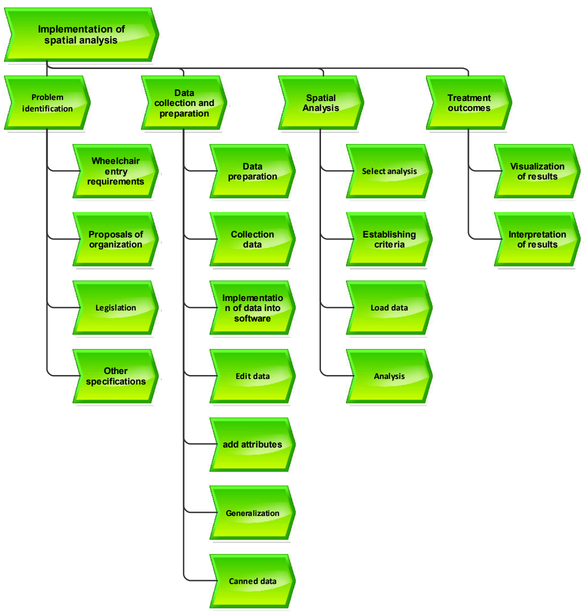

Fig. 3 – Example of function tree model

C. The Integrated DEFinition Methods

Method IDEF0 belongs to the family of IDEF methods (The Integrated DEFinition Methods), which is used for modelling of organization architecture or system. Method IDEF0 serves for the purpose of modelling of basic functions in a system or organization. It is usually used in the beginning of a system analysis. IDEF0 was derived from graphical language SADT (Structured Analysis and Design Technique) for The United States Air Force. The model consists of activities, which transform inputs to outputs, of rules that influence activities, and of tools necessary for performing activities. The diagram has precisely set rules for its creation. Identified functions are decomposed to sub-functions. Diagram IDEF0 is, from graphical point of view, based on box and arrow graphics. [17], [18]

Some of the basic elements are [17], [18]:

- Functions – records functions, which transforms input to outputs; it is expressed by a box,
- Arrows – 4 basic types:
  - Inputs – input are data or objects, which are transformed to outputs,
  - Controls – are rules for transformation of input to output,
  - Mechanisms – are tools necessary for realization of a function, for example resources,
  - Outputs – are data or objects created by the function.

It is given that function output can be input, mechanism or management of any other function.

Advantages:

- precise capturing of system functions,
- inputs, outputs, rules and mechanisms necessary for project realization are clearly illustrated,
- allows capturing of feedback,
- individual functions can be illustrated in more details by means of more IDEF models.

Disadvantages:

- does not capture order of individual activities,
- does not answer why individual functions happen,
- it is recommended to limit number of functions to one page,
- decision-making locations cannot be illustrated.

D. Flow Chart Diagram

Flow chart diagram is used for graphical or symbolic expression of a process, clarifies relations among individual process activities, detects imperfections and proposes improvements. The base and purpose of flow chart diagram is to display the subsequence of individual process steps including decision making and checking activities by means of oriented graph with added word description. Quality elaboration can only be reached by detailed, precise and profound analysis of respective system. One of advantages of the flow chart diagram is normalization of graphical signs connected with joins. Each sign has a precisely set shape and meaning and for further clarification word or symbolic operations are written within. Flow chart diagram is characteristic by the fact that individual steps of the process are successive from marked start. It is also typical that there is only one ending. [14], [19]

Advantages:

- clarity,
- plasticity,
- informs about problem solving process,
- does not need demanding software tools.

Disadvantages:

- additional changes are difficult,
- data flow could not be displayed,
- more complex diagrams loose clarity, because they would not fit on one page,
- does not capture responsible people.

E. Event-driven process chain (EPC Diagram)

Specification of managing aspect of the process. A process specified by means of EPC diagram uses, according to [15] , the following elements:

- Activities which are basic building blocks, determine what should be done within process.
- Events describe situations before and/or after performing an activity. Activities are mutually interconnected by means of events. In other words, an event can represent output condition of one activity and consequently input condition of another activity.
- Logical connectors are used to link activities and events.

That way, process management flow is described. EPC uses three types of connectors: AND – and together, OR – or and XOR – exclusive OR – mutually exclusive or. Logical connectors have two meanings in the process description. They can serve for split of activity flow or they could join these flows. In the first case, the connector has one input and at least two outputs, in the second case, the connector has at least two inputs and exactly one output.

Advantages:

- Clarity,
- Decision making precisely recorded,
- Time flow of activities,
- In an extended form organisational units, positions, data, resources, etc. can be shown,
- Can be transformed into mathematical description of a process; process then can be verified.

Disadvantages:

- A very detailed diagram so it is not good for a complicated processes,
- No functional and non-functional requirements on a system are captured

IV. Case Study

This chapter shows on examples possible usage of selected process diagrams, which could contribute to better understanding of the problem before spatial analysis itself. Consequently, they could contribute to automation of analyses and to increase the quality of repeated analyses. The solved situation addresses process of detection of barriers on bicycle routes, which could, in many cases be very similar to barriers for physically impaired people.

A. General view on spatial analysis

In the beginning, there is a functional analysis. Primary modelling components are functions and box and arrows, which mutually connect these functions.

Besides that, each function has its number identification (ID) and eventually also diagram notation, in which the function is elaborated to its further sub-functions. Because of that, it is possible to create a hierarchy of diagrams corresponding to decomposition of functions to their sub-functions (structured concept). The top of this hierarchy is defined by so called context diagram marked with a letter and number 0 (see Fig. 4). In course of diagram creation guides of their classification are followed, so that they are ordered by diagonal course and the diagram should not have less than three and more than six functions. There is also important attribute of these diagrams that outputs of given function can be inputs, management or mechanism of other functions. That way, mutual dependencies among functions are defined. [17], [18]

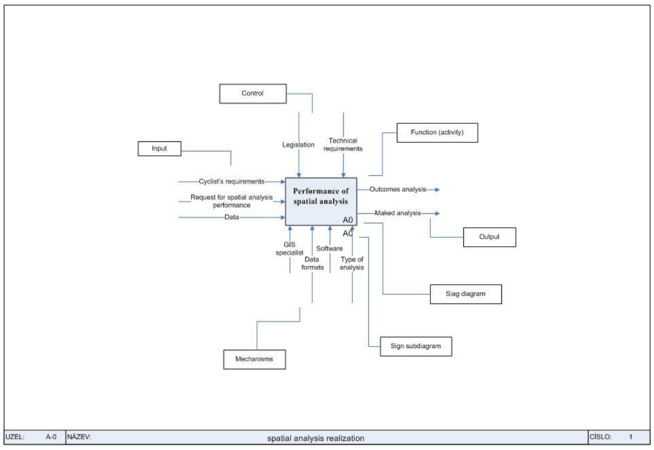

Fig. 4 – Context diagram of spatial analysis realization [20]

Function [20] *Performance of spatial analysis* (see Fig. 4) has inputs *Cyclist's requirements* – those are requests of a cyclist who, based on his/her abilities and options, requests finding the optimal route. Further input is *Request for spatial analysis performance* Essential input for performing the analysis is *Data* which would be used to perform spatial analysis.

B. Realization of spatial analysis

Realization of spatial analysis [20] is created by following three functions, which are captured in picture 5. Function *Problem identification – analysis selection* has input *Analysis requirements,* where requirements and expected results are clearly stated. Output is *Analysis specification*, which is a kind of analysis that would be used for reaching the goal. Consequently, this output is also management of the second function *Data gathering and processing* and input to the third function, which is the performance of analysis itself. This function can be structured to function *Problem identification*, which specifies individual requests for analysis (from users, office workers etc.), data valuation and analysis selection.

Function *Data gathering and processing* has all required data in respective data formats which are essential for analysis, on input. Output of this function is the required data adjusted for analysis performance; this output serves as the input for function *Analysis performance* and it is also its management. This function is further structured to other functions: *existing data valuation, provided data valuation, own ground data gathering, own tracing* and *data unification.*

The function *Analysis performance* has *Analysis specification* on input, which originated from the first function and *Essential data* gathered and adjusted from the second function. The output of this function is the analysis performance itself including creation of outputs either in text format, graphical or in form of data layer usable further in a software tool. This function is further structured to determination of criteria, which serve for management of another function, for loading data, performing analysis and generation of output with interpretation of results.

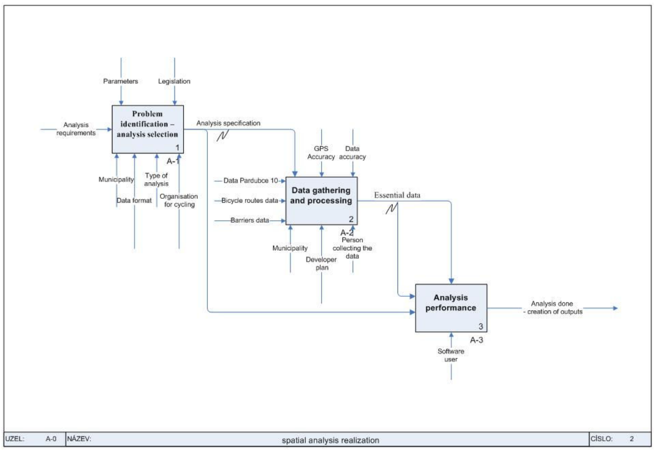

Fig. 5 – Functional specification of spatial analysis displayed by means of IDEF0 [20]

C. Analysis example I – searching for optimal way

A network can be defined as a set of line objects over which some resources flow. Network analysis can be used only for vector representation. Interconnectivity is defined based on topology [21]. Searching for way is for example in ArcGIS Desktop according to [22] based on determination of both concrete points – initial and end point, eventually also such points which we would like to visit or drive through, while minimum total distance was usually required.

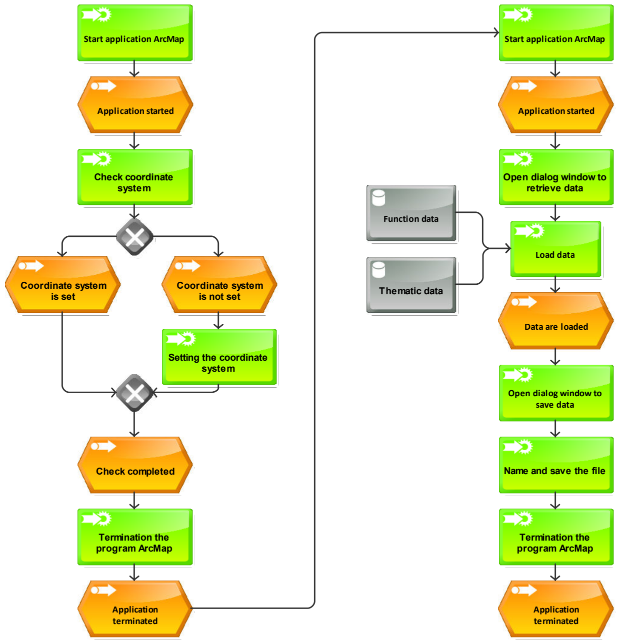

Fig. 6 – EPC diagram - Modelling of detailed view of spatial analysis -adding data in ArcGIS Desktop software

Concrete example of process model can be found in Fig. 6, 7, 8, 9, 10; in order to illustrate precise succession of activities and branching we used the EPC diagram.

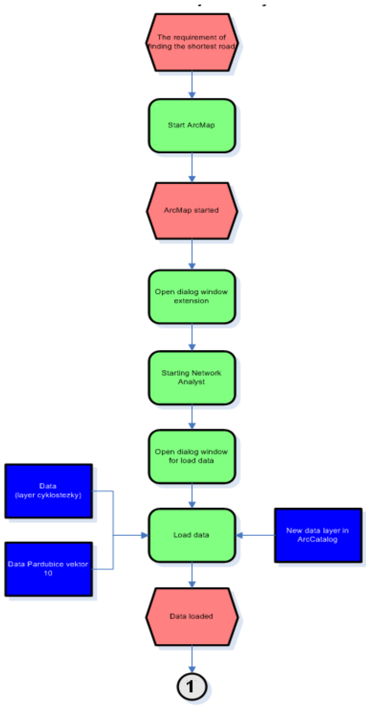

Fig. 7 – Part of EPC diagram - modelling of detailed view of spatial analysis - process of searching for optimal route [20]

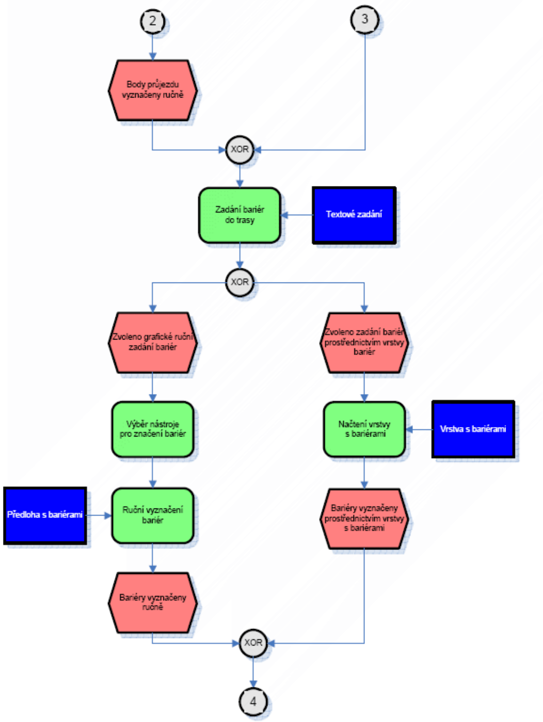

Fig. 8 – Part of EPC diagram – modelling of detailed view of spatial analysis - process of searching for optimal route [20]

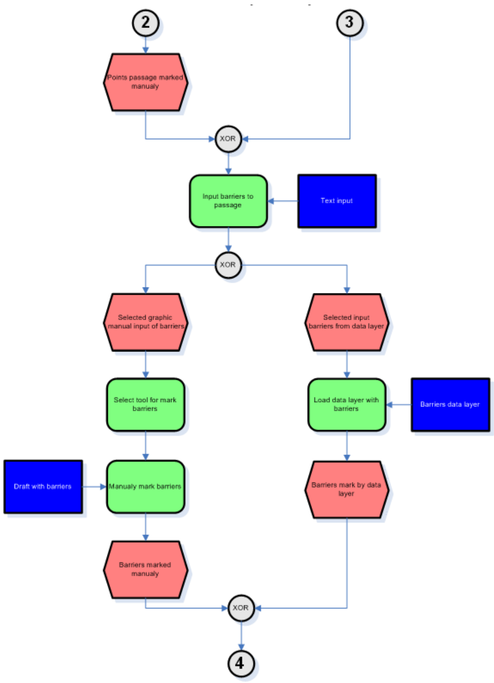

Fig. 9 – Part of EPC diagram – modelling of detailed view of spatial analysis - process of searching for optimal route [20]

D. Analysis example II – searching for routes without barriers

In order to search for a route through the city without barriers [20] we again used network analysis in application ArcGIS Desktop. For shapefile representing barriers on bicycle routes we selected shapefile representing a defect on the road. Road defects can cause trouble to cyclists and therefore the result from network analysis should make their route easier. Despite high density of barriers represented by road defects, we have proven by means of network analysis that routes without barriers do exist.

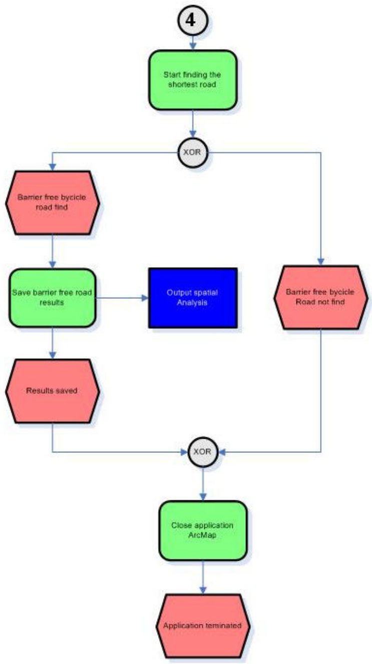

Fig. 10 – Part of EPC diagram – modelling of detailed view of spatial analysis - process of searching for optimal route [20]

From the data which represent barriers we selected shapefile with road defects because they represent a significant risk for cyclists and it is not easy for cyclists of any age or experience to deal with these road defects.

Two routes through the city of Pardubice were generated – one leading from east to west, the other form north to south. In both routes there were two options generated – one possible way without barriers, which were mostly roads in bad shape, and the other was the shortest possible way, which did not consider barriers. The result indicated that in both cases the route without barriers is longer. From east to west the route is 462 meters longer and from north to south it is 952 meters longer. One kilometre longer route can be unsuitable for many people and it could look too long and time consuming and that is why they use route with barriers to pass through.

V. CONCLUSION

Improvement of spatial data processing are common part of public administration portals where is accent to their usability [23], [24], [25] .

In the article, modelling of spatial analyses processes for detection of barriers on bicycle routes has been described. Modelling of these analyses allows understanding of given problems in course of solving barrier-freeness and it allows this solution even for those people who do not occupy themselves with spatial analyses. For modelling of processes it is important to choose suitable process diagrams. For evaluation we selected diagrams IDEF0, EPC, development diagram and Use Case diagram. Suitability of individual process diagrams can be evaluated by means of a number of criteria. Advantages and disadvantages of individual diagrams were summed up within the study and based on that the suitability of individual diagrams.

In the case study, diagram IFEF0 was used for modelling of spatial analyses processes on a basic level, due to its predicative ability, clarity, good input, output, necessary sources and managing rules recording.

For more detailed spatial process modelling including preparation of data of level of individual activities we selected modelling by means of EPC diagram (Event-driven Process Chain). Advantage of EPC diagram is illustration of activity order of decision making locations. EPC allows illustration of decision-making in process. From this point of view EPC diagram seemed very suitable, because for expression of decision-making it allows using not only logical operators, but also possibility of concurrence of more processes and decision alternatives. It is a more detailed and complete expression of decision-making process than in, for instance, development diagram, which allows only yes/no options. On the other hand, IDEF0 and Use Case diagrams are quite unsuitable for expression of decision-making.

EPC diagram also seems to be very efficient for detailed process description. The advantage of the Use Case diagram is more complex view on given process and to activities appertaining to individual process actors for a price of less details and worse expression of individual activity order. Since actor role was mentioned, participation or even responsibility for this process can be captured in a diagram. The development diagram is not capable of expressing such responsibility - EPC diagram is more suitable for this task, since it is capable of expressing responsibility for concrete function or even whole process. IDEF0 is capable of expressing detailed responsibility of concrete actor for concrete activity within process, similar to the Use Case diagram.

An important characteristic of the process is its time delimitation; that is why it is important to capture the order of individual phases of process from time point of view. The order of individual process phases is expressed in a clear and detailed manner in development diagram and EPC diagram. Both diagrams capture individual phases of the process with relation, which are logically ordered by time consequence from the beginning to the end. On the other hand this time consequence is not captured in Use Case diagram or IDEF0.

The main goal of modelling of processes described above was to record complex processes for solving spatial analyses so that all the elements, processes, and sources are recorded. These processes were recorded in such manner that a person who would like to occupy himself with given problem or who would like to use the data could perform without much thinking or decision-making over subject matter with suitable precision and quickness.

In the future, further diagrams are planned to be constructed and a list of quality requirements for input data to be written down, so that it would be possible to use models created for automation of carrying out spatial analyses. An example of output which allows fully automated realization of spatial analysis is the model created in ModelBuilder in program ArcGIS Desktop.

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