A METHODOLOGICAL APPROACH TO IMPROVE KNOWLEDGE EXPLICATION FROM LOGISTICS SIMULATION PROJECTS

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ABSTRACT

One of today's challenges consists in seeing simulation in the context of human-centered processes. This requires understanding simulation as complex problem-solving, knowledge-generation and learning process but simultaneously as tool to support teaching and subject of knowledge application. Hence, the paper applies a knowledge management perspective to logistics simulation projects. Knowledge flows in the course of a project are analyzed and a method for continuous knowledge documentation is introduced to enable human resources involved in a simulation project to act properly as knowledge stakeholders and knowledge users to the benefit of the project; and also to strengthen the other role of simulation – to be a very valuable methodology and tool for the acquisition and storage of knowledge about the structure and organization of logistics systems and about processes of lasting effect for running, maintaining or even re-designing them. Finally, the vision of an automatically generated simulation project report is developed. With this, the paper describes ongoing research the results of which will not only be relevant to logistics simulation but applicable to other application areas of simulation, too.

INTRODUCTION

Discrete event simulation has widely been accepted as appropriate method and tool to support planning, implementation and operation of logistics systems and processes. Furthermore, there is a well accepted standard procedure of how a simulation project in logistics is to be run. As VDI 3633 explains this includes steps for problem, system and process analysis, model building and implementation, planning and running experiments as well as interpretation of outcomes and presentation of results. In general, simulation projects in the field of logistics are organized in the form of a service involving both, simulation experts and logistics experts. These partners provide different expertise and knowledge to be of use in the different stages of the simulation project: Whereas simulation experts are primarily responsible for model building and implementation, logistics experts mainly provide application-specific knowledge to specify the problem, identify input data and evaluate results. Neumann and Ziems (1997) identified a gap in communication, exchange and understanding between these two worlds of a simulation and proposed a cooperation model to ensure permanent communication between the knowledge stakeholders of the simulation project. With this each partner brings in unique competence and knowledge to the benefit of the joint project (see Figure 1).

Consequently, a simulation project must not only be seen as a problem solving process. Instead it is a process of knowledge generation and acquisition as well. Unfortunately, information about decisions taken when building the model or running experiments as well as really new knowledge about the particular application or even about the simulation methodology gained in the course of a simulation project quite often stays in the heads of the people involved in the project. It is not externalized in a sufficient way, because documentation tasks are time-consuming, seen as an add-on to the real problem solving process and not well supported. As a result project-specific knowledge on assumptions, decisions, modeling philosophy, experiments and results is not kept and gets lost even with the persons who had been involved in this particular project.

Against this background, research on implementing a knowledge management perspective in logistics simulation projects addresses the following questions:

- Which information and knowledge is needed by whom at what stage of a simulation project?
- Which knowledge and information is provided by whom in which step of a simulation project?
- Which knowledge is generated with whom in which step of the simulation project?
- How communication and understanding between simulation and logistics experts can be improved?
- How project-specific knowledge about assumptions, decisions, levels of detail etc. can be externalized from the heads of the partners involved and how it can be formalized and kept?
- Is there any opportunity for the automatic generation of a simulation project report draft?

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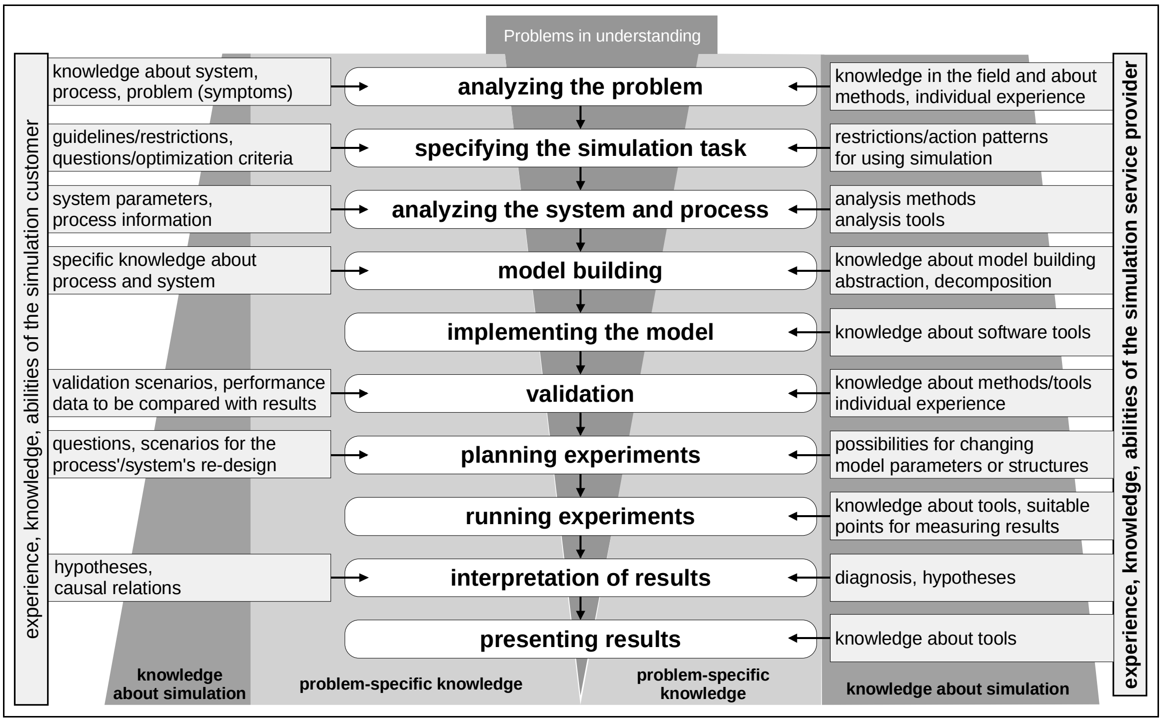

Figure 1: Knowledge Stakeholders in a Simulation Project (Neumann and Ziems 2002)

KNOWLEDGE AND KNOWLEDGE SOURCES IN LOGISTICS SIMULATION PROJECTS

Knowledge is generally defined by Beckman (1999) as reasoning about information and data to actively enable performance, problem-solving, decision-making, learning, and teaching. In logistics simulation as in any other kind of problem-solving this knowledge is to be related to both the subject of the simulation study and the procedure of the simulation project. In general, logistics simulation knowledge can be described as entirety of specific or generalized theoretical or experienced knowledge about the simulation problem and its solution (subject-related knowledge), but also about the procedure and organization of the simulation project (procedure-related knowledge) that either explicitly or implicitly exists or is created in the course of the simulation project (Neumann 2005).

In particular, subject-related logistics simulation knowledge comprises:

1. *Domain-specific knowledge* necessary to clearly understand specifics and constraints of the application area. In our case this refers to general knowledge about logistics and material flows on one hand and complementary knowledge from related fields such as material handling technology, automation and control technology, ergonomics, or economics and management on the other hand.

2. *Problem-specific knowledge* unambiguously characterizing the specific problem to be solved in this particular simulation project. In logistics simulation this includes knowledge about
   - the logistics system (e.g. structure, layout, technical or geometric parameters) and the logistics process (e.g. activities, flows) to be investigated,
   - logistics objects (i.e. goods, pallets, eventually trucks or other moving entities) affected by them and
   - interfaces with or links to the system's environment (e.g. sources, sinks, incoming/leaving flows, system load) to be taken into consideration,

   but also knowledge about
   - the question, goals and constraints of the simulation.

3. *Solution-specific knowledge* describing the outcomes of the simulation project. This covers all knowledge explaining how the given or identified problem might be solved. Depending on the current stage of the problem-solving process and phase of the simulation project it consists in two ways. Hypotheses on how a possible solution to the given problem might look like can refer to an appropriate system/process design, resulting system behavior, maximum system performance or any other target characteristics of relevance. Output data or results in the form of system characteristics (e.g. performance indicators) and recommended designs or modifications of a planned or existing logistics system and process evolve in the course of the

simulation project to answer all questions directed to the simulation.

In contrast, procedure-related logistics simulation knowledge includes:

1. *Methodological knowledge* necessary to run a logistics simulation project. This refers to simulation knowledge such as modeling and discrete-event simulation methodology, experimental design techniques, validation methods or simulation tools, but also to underlying concepts from problem-solving and decision-making, mathematics and statistics, queuing theory.
2. *Management knowledge* covering all aspects of the strategic and operative management of the simulation project such as project organization, team building, roles and responsibilities in the simulation project or knowledge sources/ stakeholders.

As shown in Figure 2 logistics simulation knowledge combines aspects from a wide variety of subjects and logistics simulation projects require a respective collection of interdisciplinary expertise. Furthermore, logistics simulation knowledge is dynamic and always evolves in the course of a project.

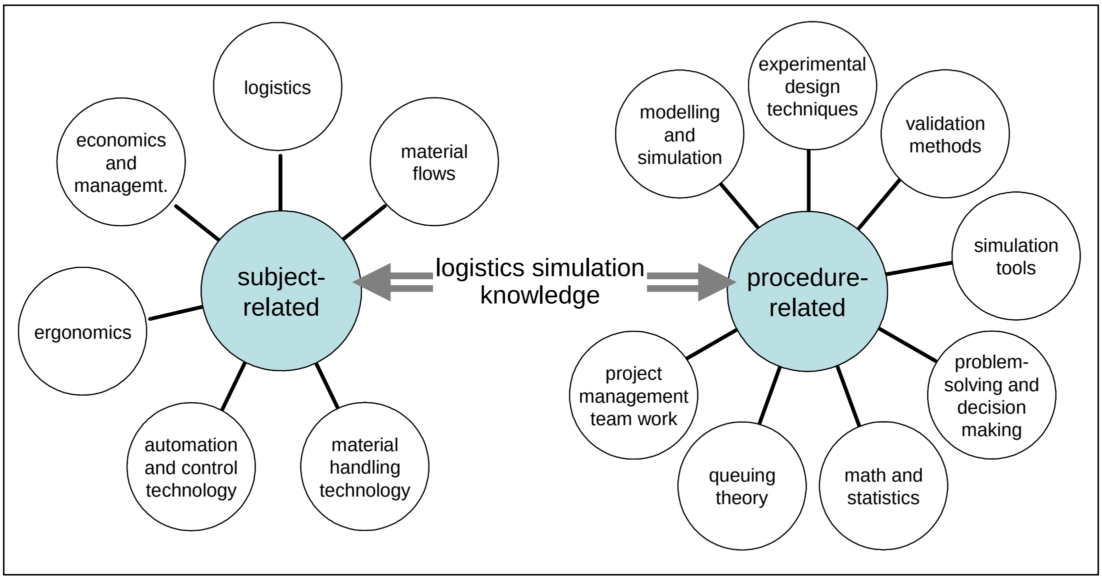

Figure 2: Logistics Simulation Knowledge (Neumann 2005)

Correspondingly, there are numerous and diverse sources and holders of logistics simulation knowledge. Input information to the project usually come with the tender specification for the simulation project or are to be identified and generated in the problem definition and data collection phases of the simulation. Procedure-related knowledge and even more solution-specific knowledge are represented in the “products” of the simulation project. The simulation model, for example, is not just a tool for experimentation but also a kind of a dynamic repository containing knowledge about parameters, causal relations and decision rules gathered through purposeful experiments. Unfortunately, this knowledge is not very well documented and therefore exists implicitly only inside the simulation model. Thus one continues to find a break and discontinuity in applying simulation results. Knowledge important for the realization of simulated functionality is lost and needs to be re-developed by renewed implementation and testing. Even the obligatory project report and presentations contain selected, focused parts of this knowledge, only.

To overcome this unpleasant situation consistent, up-to-date knowledge about the simulation model and its developmental process needs to be gathered directly from and continuously during the simulation project. To achieve this, all participants in a logistics simulation project, i.e. simulation experts and logistics experts, need to be encouraged (and supported) permanently to provide background knowledge about his or her motivation for going in one rather than the other direction, for changing the model structure or parameters in a certain way, for keeping a particular type of possible solutions and abandoning others, for looking for information, knowledge and support from one source instead of another. This procedure will work only if it is directly integrated into the “normal” simulation activities – with no or little extra effort. Techniques like structured documentation, continuous exchange or ongoing reflection and generalization help to cope with this and to master complexity and dynamics to the benefit of both a logistics simulation project in particular and logistics simulation methodology in general.

APPROACHES TO SUPPORT SIMULATION KNOWLEDGE ACQUISITION AND SHARING

Taking into consideration the needs for supporting knowledge exchange and storage in simulation projects, a number of relevant approaches can be found in literature and implementation:

Brandt et al. (2001) describe a case-based approach to gain *experience-based knowledge on project management* in the field of software engineering and make it available for re-use in future projects. For this, all kinds of experiences, e.g. templates of documents, guidelines, observations, problems and their solutions, proposals for improvements and lessons learned, are gathered from interviews with project team members and stored in a central repository, the experience base. Applying this method to logistics simulation projects, acquisition and sharing of simulation management knowledge as explained above could be supported. In the end, this would allow a new simulation project to directly benefit from previous projects with similar simulation goals, application areas or re-usable models.

Simulation-specific collaboration infrastructures aim to support knowledge exchange within a particular simulation project and knowledge sharing within a wider simulation community. For example, the Web Based Simulation Center (WBSC – http://www.b2bsim.de) offers simulation services and software renting via application service providing (ASP) on the web to initiate business relations, to support communication and cooperation in the course of the simulation project, to run simulation models and to present simulation results (Lorenz 2003). The Virtual Centre for Simulation (Sim-Serv – http://www.sim-serv.com) as another example has been set up to provide a one-stop shop where the full range of simulation technologies may be accessed in one place, rapidly and on-line. Apart from an independent support for users to define and manage their projects a permanently updated knowledge pool containing general information about the simulation methodology and technology is offered. Those services help to bring together simulation expert and domain expert and, with this, might form the technological fundament of a common simulation portal.

Some of today's simulation packages offer functionality to automatically generate a *verbal model description* out of more or less abstract model structure, layout and parameter information. DOSIMIS-3 (http://www.sdz.de), which is a simulation package for material flow and logistics simulation, forms an example for this user-friendly support. This way, a model and its specifics can be explained to non-experts in the syntax and language of a particular simulation tool. But still, the reasons for building the model that way, for setting particular parameters or defining decision processes are not covered by this and remain hidden.

To present a person's individual impressions on a model's behavior and his/her understanding of simulation results to the computer, Helms and Strothotte (1992) first mentioned *viewpoint descriptions* as a tool initiating reasoning processes on necessary changes to the simulation model. They introduced this specific method called oracle-based model modification into simulation model validation as a new kind of communication and interaction between the human observer of simulation results and the computer as the simulation model using authority. In general, a viewpoint description represents an individual view on existing things in a formalized way. It consists of a documentation part describing the initial state of the cognitive object (including qualitative statements and causal dependencies) and a criticism part describing its target state in the form of assessments, problems and tasks. Neumann and Ziems (2002) recommended to apply the viewpoint description approach to provide a systematically and continuously growing formalized description of the simulation expert's or logistics expert's personal view reflecting the current state-of-knowledge and understanding about the simulation problem (and its solution) and the problem solving process including all changes in the course of the simulation project. But to really make use of this particular approach to acquire and store logistics simulation knowledge, the documentation frame as originally delivered requires further structuring and definition of knowledge categories to be represented. The main challenge consists in being as general and as domain-specific as possible at the same time.

Summarizing the current state-of-research with regard to supporting knowledge explication in simulation projects in general and in logistics simulation projects in particular, it can be stated that the research questions as mentioned earlier are not answered yet. Furthermore, technical implementation remains difficult; already implemented functionality is scattered across various existing software solutions. Approaches to document methodological simulation knowledge, a comprehensive approach for seamlessly integrating respective functionality into the simulation tool as well as a formalized documentation structure are still missing.

METHODOLOGY FOR STRUCTURED SIMULATION PROJECT DOCUMENTATION

To develop an appropriate documentation structure and methodology, a logistics simulation project aiming to compare principal solutions for crane-operated container storages has been accompanied from an external observers point of view. The goal of the simulation service was to gain findings on the economically more efficient and technically better performing crane design under varying scenarios and performance requirements. To learn about knowledge flows in the course of the project and identify relevant knowledge categories for the documentation all document and information flows as well as information forwarded with them or in meetings were recorded. From this, a structure and procedure to describe the simulation model as well as the simulation project and its results in a formalized way have been derived.

A first result is formed by a specific documentation structure for recording a project meeting (see Figure 3). This framework does not only consist of categories with typical information on a meeting, such as location, time, participants etc., but more important it allows collecting detailed knowledge about the particular simulation project. For the latter, subject-related knowledge was clearly separated from procedure-related knowledge and individual sub-categories for both knowledge aspects have been defined. Following the basic structure of a viewpoint description each knowledge category contains a documentation and a criticism part with problems and tasks. Whereas the documentation part of procedure-related knowledge represents the main aspects of a simulation-based problem-solving process in general, the documentation part of the subject-related knowledge was specifically structured according to the application area of logistics. Consequently, on the first level it is further divided into object, system, process and environment categories which are suitable to completely describe a logistics problem and solution. If the proposed documentation framework is to be applied to any other application area of simulation, this specific part would have to be adapted to the relevant elements of problems and their solutions in this particular area.

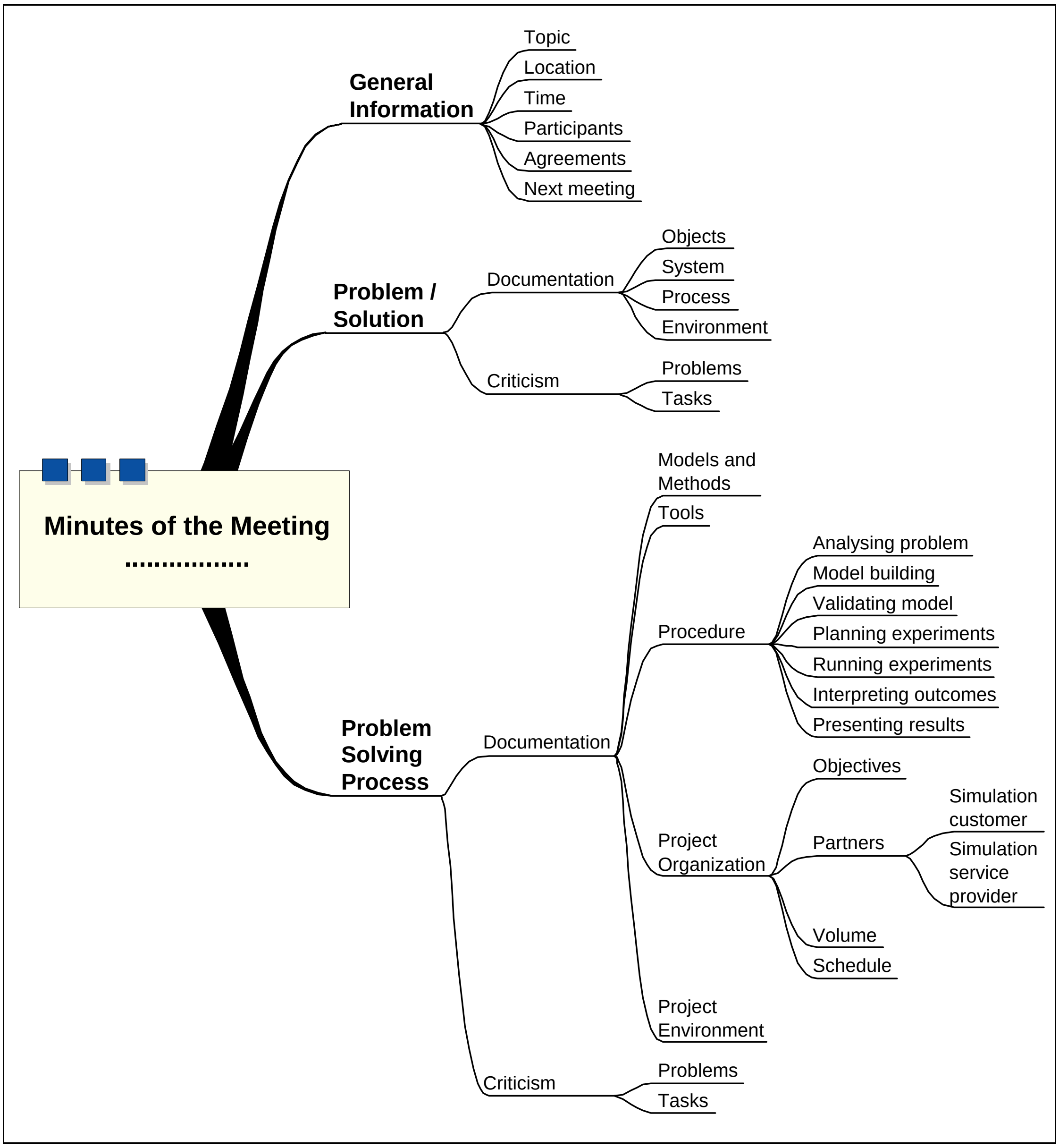

Figure 3: Structure for Documenting a Project Meeting (Minutes of the Meeting)

In each project meeting one copy of this template has been filled with the particular contents and results leading to a growing set of documents with structured simulation knowledge. In addition to this, further exchanged documents, written or oral communication outside the meetings and further external knowledge sources used within the project have been analyzed in a similar way and increased the project-specific knowledge collection. From step-by-step uniting all of these individual documents according to the project progress, a project-accompanying structured documentation of both the state-of-the-problem (and solution) and the state-of-the-problem-solving (including the state-of-development of the simulation model, methods and tools used or decisions taken) was derived. Here, the suitability and appropriateness of the structuring approach has been proven useful, because all information and knowledge elements could be included into the framework independent of their source. At the same time the state-of-documentation resulting from each newly added source of knowledge also represents the particular state the project had reached at that point in time. With this, not only moment-specific representations of project knowledge, but also period-related representations of project progress become storable in a formalized way. Due to the fact that knowledge on the problem or solution and knowledge on the project procedure are always jointly documented, not only a purposeful reflection of taken decisions is required, but also a clear explanation of all modifications to the model, procedure or solution initiated by those decisions. Together with the corresponding files containing the simulation model this would principally allow to return to any point in the problem-solving process and continue from there towards a different path whenever this seems to be necessary or appropriate.

In the course of a simulation project, especially if it is a more complex one, the resulting documentation tree might reach a high level of complexity and could hardly be graspable. Because of this, further research is currently oriented towards identifying suitable general sub-structures of the problem-/solution-specific documentation categories. Input for this is provided by the generally defined classes of logistics simulation data (i.e. technical, organizational and performance data - see VDI 3633) and also by further approaches to characterize logistics processes, systems, models, problem-solving methods and heuristics in a standardized way.

CONCLUSIONS AND FURTHER RESEARCH

Human resources involved in a simulation project are the key factors for its success and efficiency. As discussed in this paper, the different background knowledge and expertise of the simulation and domain experts who jointly run the project produces a considerable need for cooperation and with this for communication and explanation as well as mediation, moderation and translation. The basis for successful collaboration is an ongoing, well-defined and well-structured documentation of the simulation model, simulation runs and the simulation project with all its assumptions, agreements, and decisions. Here, the main challenge consists in explicating and keeping all aspects of knowledge specifically used and generated in the course of the simulation project (see Figure 4). This knowledge equally covers fundamental parts which are independent of the application area and strongly application-specific parts which have to be represented by the documentation framework as well.

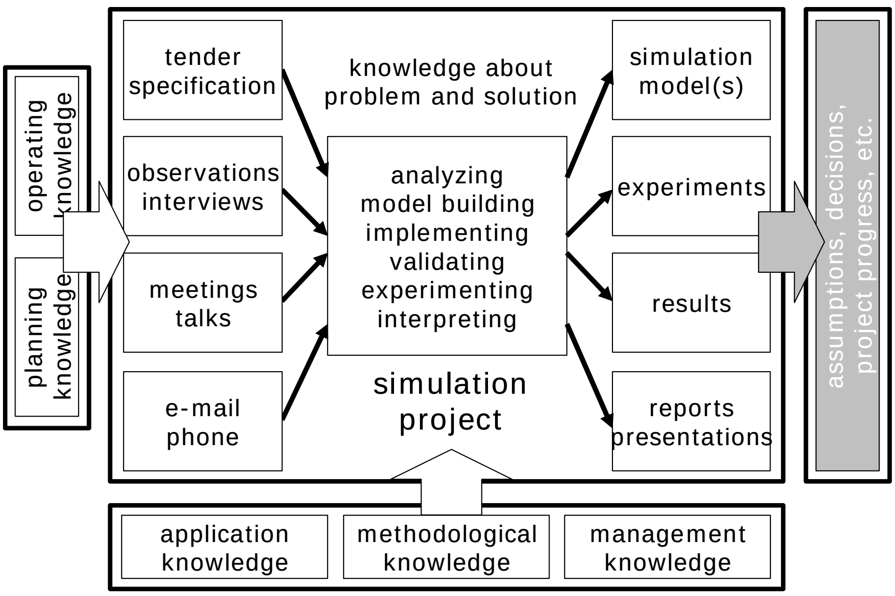

Figure 4: Sources, Evolution and Gaps in Logistic Simulation Knowledge

The methodological approach as proposed in this paper meets this challenge. It helps to identify who knows what about the logistics system and process, but also about the simulation project behind it, why something was decided in which way, which system configuration and which set of parameters worked how well together, what is represented in the simulation model and what are the limitations of its validity and usability. With this the process of a simulation project becomes a process of knowledge creation and acquisition at the same time without too much additional effort for all involved. The clue to the successful implementation of those knowledge management procedures is often an appropriate (supporting) environment and climate in the organization. Concerning this, there is often a greater need for a cultural shift than for additional software tools and IT solutions.

Taking the latter into consideration a questionnaire-based survey is running with the user group of the DOSIMIS simulation package to understand who is documenting what for what purpose and by when in the context of a logistics simulation project. This is expected to provide some deeper insights in the current documentation culture with simulation service providers. Furthermore, individual needs and wishes for supporting documentation efforts in general and with respect to the particular simulation tool are questioned to gain a clear picture on deficits and the potential acceptance rate of a respective software solution. Although the survey is addressed to a small and focused sample of simulation experts the findings will allow specifying functional requirements for supporting tools and even more identifying access points to strongly motivate the implementation of the approach of a structured documentation framework.

In principle, application of the approach might offer a number of chances:

- To support an ongoing communication between the partners in a simulation project for achieving a common understanding of the logistics process and system to be investigated;
- To avoid any loss of information and knowledge in the course of the simulation project;
- To provide a kind of check list for data collection and a template for model design straight at the start of the project (What is to be taken into consideration for model building? Which information are required for the investigation?);
- To (automatically) create the draft of the simulation project report directly from the ongoing project documentation (including all assumptions, agreements, decisions).

Especially the vision of an automatically generated simulation project report is expected to address a particular need within the simulation community, because producing a report on the simulation project adequate to the processes and results is quite time-consuming and does not belong to the most-welcomed tasks within such a project. But the benefits that might be achievable by this are not only related to time-saving aspects and the increase of a simulation project’s efficiency, but even more to provide a means for quality assurance. Pre-condition for this is in any case to embed the documentation task into the “ordinary” problem-solving activities as seamlessly as possible. For this, comfortable interfaces and links to the simulation tools need to be developed or an extended functionality for commenting and annotation is directly to be integrated into them. Ideally, the main part of the project knowledge to be documented is directly (and in this way hidden to the persons involved in the simulation project) taken from documents and models which are produced in the project anyway as well as from tools which are commonly used for experimentation purposes or statistical analysis of simulation outcomes.

For bringing this vision to reality, future work as discussed is to be spent on the further formalizing and sub-structuring of the proposed documentation structure and also on its implementation into appropriate supporting software – if at all possible directly linked to a widely used simulation tool.

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