**Journal of Simulation (2013) 7, 240–248** © 2013 Operational Research Society Ltd. All rights reserved. 1747-7778/13
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# Delphi Study on evaluating information in simulation studies for manufacturing and logistics planning

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Information is the key resource for performing simulation studies in manufacturing and logistics planning. To build the simulation model and to subsequently collect the requested simulation results, this information must have the necessary level of quality. To evaluate the influence of information quality on the quality of simulation study results, it is first of all essential that the quality of information be assessable. However, to evaluate quality, it is also necessary to know which information in the context of simulation studies will be deemed as generally relevant. To clarify this question, a Delphi Study about information in simulation studies was conducted. Based on the results of this Delphi Study, a basic overview of the relevant information for simulation studies in manufacturing and logistics can be given in a clearly arranged list.
*Journal of Simulation* (2013) **7,** 240–248. doi:10.1057/jos.2013.7; published online 22 March 2013

**Keywords:** discrete-event simulation; information gathering; Delphi Study; production; logistics

## 1. Introduction

A Delphi Study is a kind of expert interview in the form of a multistage process with several rounds of questioning. It is based on the operationalization of a problem using measurable evaluation criteria. Subjective factors (which may arise in a group discussion) can be avoided by keeping the experts anonymous. Through this multi-stage process different results and the scattering of these results will be reduced (Häder, 2009).

For the Delphi Study presented in this article, a preliminary study was conducted with the goal of creating a preliminary overview of the information relevant to simulation studies. Based on this preliminary study, qualified simulation experts from the fields of research and industry were asked to evaluate this information according to their importance. Additionally, the experts had the opportunity to define unlisted but important information and to give their opinion. The experts were also asked to organize the evaluated information into categories. These categories were also identified in the described preliminary study.

The aim of the final Delphi Study was to determine which information has an essential relevance to the successful execution of a simulation study and how different degrees of the significance of identified information can be defined. The categorization of the relevant information was important in order to develop a summary of information that can be used to get an essential overview of the main fields in simulation studies and the related information.

Against this background, the article shows which results in the Delphi Study on Evaluation Information in Simulation Studies for Manufacturing and Logistics Planning were achieved, and how these results could be used in further research activities.

## 2. Information in simulation studies

Because of the variety of contexts, there is no concurrent definition in scientific literature for the term ‘information’ (eg Attneave, 1974 or Bonfadelli, 2001). However, all definitions have one feature in common, that information is always a part of the communication between a sender and a receiver, the objective being to eliminate the receiver’s lack of knowledge. With regard to contents the term ‘information’ represents an extension of the term ‘data’. According to the understanding of knowledge management, data consist of single characters. If the syntax for a character order is defined, they can be considered as data (North, 2005). And if these data have a meaning, a so-called semantic, for the receiver, they can be called ‘information’. With this understanding of information, the underlying data have always to be taken in account. This article focuses on project management information (eg time scheduling) as well as information in the form of classical input data (eg cycle times). The results of this Delphi Study reveal a basic overview of this kind of relevant information. The content of

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the information is not relevant in this case, because the respective simulation study itself only determines the content of the information. That is why the resulting overview shows so-called information types, which serve as placeholders for the possible information.

For simulation, and in this context also for discrete event simulation (Pidd, 2004; Robinson, 2004; Law, 2007), which is one of the most important experimental problem-solving methods for analysing complex manufacturing and logistics systems (Wenzel *et al*, 2010), information is the essential resource needed to obtain the requested results in the requested quality. Not only the amount of information is relevant, it is also important that the required level of quality is achieved. Examples of these factors include the source of origin, the clarity of the presentation or the accuracy of the information that is requested. In his works, Lochmann shows the high relevance of information, especially for decision-making processes (Lochmann, 2006). For example, in the simulation this is demonstrated by assessing if there is a need to use simulation at all. The sum of all the decisions in a simulation study based on the available information leads to the final simulation model and to experimentation and analysis, which provides the simulation results.

According to the above-mentioned reasons, 'the quality of the results of simulation experiments cannot be better than the information on which the simulation experiment is based, ie, simulation results are useless or misleading if the data base is faulty or if the results are interpreted in the wrong way' (VDI, 2010, p 6). In this context, quality is defined as the fulfilment of specific requirements and not as the quantitatively best possible quality. So it is possible to have the required quality, although the underlying information could be even 'better'. As a result, the identification of the specific need for information in simulation studies and the subsequent acquisition of this information is a non-trivial process, because the simulation user always needs to have a high level of knowledge concerning the character, the scope, the source and the quality of information (Wenzel *et al*, 2009 or Kuhnt and Wenzel, 2010).

To execute a simulation study, the relevant information must be available for the simulation expert. This information can usually be derived from the enterprise data or from expert know-how at the awarding authority. It is possible for the required information to change depending on the goal of the investigation, the systems to be analyzed, or the awareness during the model building process. That is why a review of this information is inevitable and iteration arises for the process of its acquisition.

## 3. Basics of the Delphi Study on evaluation information

The Delphi Method was named for the oracle of Delphi (800 BC) and it is understood as a multi-stage survey of experts with feedback (Hesse *et al*, 2009). This method makes it possible to gather different objective expert opinions for the purpose of consensus building, because the anonymous sending and transmitting of the expert opinions avoids negative influences. These influences can occur because of the status or the seniority of participants (Schulz and Renn, 2009). The applicability of a Delphi Study as a method for consensus building to address complex problems can generally be justified by the definition of Linstone and Turoff (1975). They define the Delphi Method:

> […] as a method for structuring a group communication process so that the process is effective in allowing a group of individuals, as a whole, to deal with a complex problem. (Linstone and Turoff, 1975, S. 3)

In principle, the possible applications of Delphi Studies are far ranging. For example, the method may be used to identify indicators that measure the social effects of power generation technologies in Europe (Gallego Carrera, 2009), or it can be used for the prognosis of future development of universities in Germany (Gregersen, 2011). Of course, the Delphi methodology will not work as a solution for all conceivable problems. However, the characteristics of consensus building using Delphi-typical iteration as well as the anonymity of the participants demonstrate the suitability of the method for the purpose of this overview. A simple query of possible information, for example using questionnaires, could lead to a complication in the consensus-building process. In this case, there will probably be many rounds of questions or in the worst case no consensus of expert opinions will be found. Moreover, conducting interviews seems to be rather unsuitable in this case. There will be no list of all the expert opinions in which the respondents had the opportunity to reconsider their own opinion because not all the interviews can be carried out simultaneously. The group interview method could solve this problem, but this would lead to the problem of the influence due to the lack of anonymity.

Because of the suitability of Delphi Studies for the identification, evaluation and classification of relevant information or rather information types in simulation studies, the Department of Organization of Production and Factory Planning (University of Kassel) conducted a Delphi Study to identify these information types. In this context, the term 'information type' can be understood as an initial summary of certain information in order to be able to summarize possible expressions of one kind of information as a first step.

Figure 1 shows the typical procedure when performing a Delphi Study, starting with the derivation of evaluation criteria from a general problem up to the described iterative process with the goal of focusing the expert opinions, as shown in the last two steps of the figure.

The first step of the diagram shows that evaluable criteria have to be derived from a general problem. Just as in other social science studies, one needs to systematically prepare the

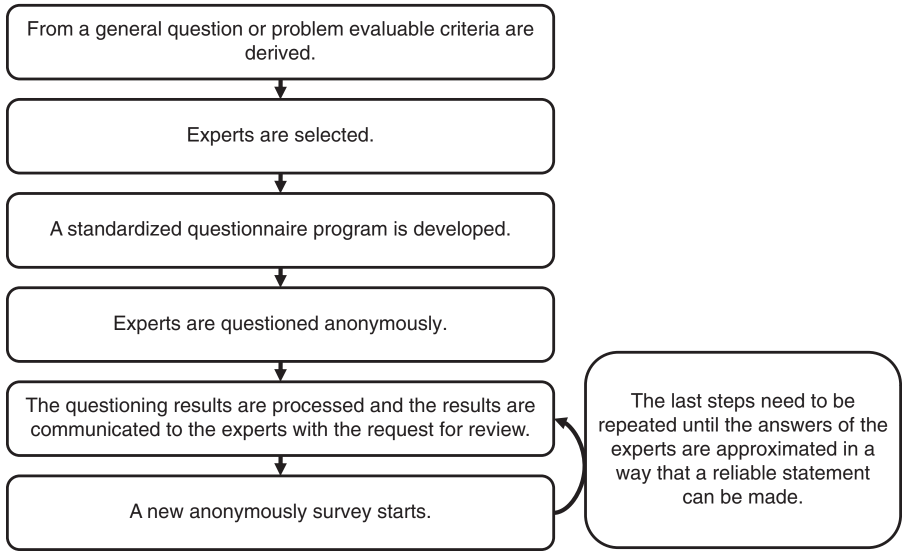



**Figure 1** Typical steps of a Delphi Study (own illustration).

questions in a Delphi Study, so that it can be provided to the experts in an operationalized questionnaire (Häder, 2009).

In the second step experts are selected. In contrast to other methods, no estimate of the minimum number of experts in the context of a Delphi Study can be given because some problems are so specific that only a few experts in these areas can even be found. That is why there is information about the number of experts in Delphi Studies with only 10 participants (Westhaus, 2007) as well as information about studies with more than 800 participants (Gregersen, 2011).

In the third step, the question program has to be worked out according to the chosen operationalization from the first step. For this purpose, the survey medium, the distribution of the questionnaire and other organizational tasks are determined, so that a questionnaire is available that can be sent to the experts in the fourth step.

In the last three steps the results of the survey are analysed and sent to the anonymous experts. The experts have the chance to reconsider their previously selected responses in the finished survey iteration. This iteration leads to a gradual compression of individual opinions and leads to a more consistent group result (Hesse *et al*, 2009).

Based on these theoretical principles, identifying the relevant information in simulation studies can be made via the help of a Delphi Study. Furthermore, with the help of a Delphi Study one can analyse if it is possible to find a classification for the information identified.

## 4. Design and implementation of the study

The formal process and the design of the study were based on the procedure shown in Figure 1. Six steps were run through and the last two steps were repeated three times, so that a total of three question periods were performed.

The aim of the first step was to derive evaluable criteria and to develop the operationalized scheme. The two essential issues of the Delphi Study, namely, the decision about the information that is relevant for performing simulation studies and the decision about the possibility of an aggregation of information types were split, so that basically a two-part questionnaire were set as the target format. To keep the scope of the study manageable, a preliminary study with a simulation service provider was performed in the form of individual interviews before the Delphi Study was conducted. The result of this study was a preliminary list of important information types as well as the initial proposals for possible categories. In the design of the Delphi Study, an assessment between 0 (not important) and 5 (very important) for the previously identified information was chosen as part of the implementation of evaluable criteria. The possibility of categorization was implemented in a way so that the experts were able to classify the identified information in proposed categories. The percentage agreement of the classification between the experts was set as evaluable criteria for this part of the study.

In the second step, the potential experts for the Delphi Study were selected. For this purpose two key priority selection criteria were set as requirements to participate in the study. The first requirement demanded that the participant have many years of active simulation experience. The second requirement determined that experts in the logistics planning as well as experts in the field of research should participate in the study. This leads to certain heterogeneity among the participants regarding the application areas of simulation.

Because of these requirements, experts from the ASIM[1] were explicitly asked to take part in the study. With the focus of the ASIM it could be ensured that, in addition to the necessary knowledge about simulation applications, the associated methodological knowledge would also be available. These restrictions resulted in a total of 20 experts who were asked to participate in the Delphi Study. For reasons of anonymity and the lack of space, there will be no description of the characteristics of each expert at this point.

In a third step, the question program from the first step was implemented in a formal questionnaire. It was then possible for each of the participants to answer the questions of the Delphi Study as clearly as possible. For the evaluation of the importance of information in simulation studies, a total of 36 previously identified types of information have been presented to the participating experts. With the help of this approach we could ensure that the identified information types have an importance for simulation studies. In addition, the experts had the possibility to define further information types independent from the previously identified types. As for the categorization of the information types, the experts could classify the types from the first part of the study in five categories. If the given categories did not reflect the experts opinion, the experts could, similar to the first part of the study, define additional categories and classify the information types in these categories.

The essential task of the fourth step was the actual questioning of the experts. The survey was performed digitally with the previously developed questionnaire. The experts did not know about the other participants in the study, so that anonymity was guaranteed within the group. The digital questionnaire was sent via e-mail to the experts. The experts answered the questions and sent the questionnaire back to be evaluated. In addition to the questionnaire described in the third step, the document contained detailed instructions and description of the study, so that an understanding for the methodology and the process could be established.

In the fifth step, the results of the experts were prepared. The average for the assigned significance was formed and additional information that was judged by the experts as important was identified. This, as well as an overview of the specific answer of each expert has been implemented in the questionnaires. The overview was different for each expert because of the different answers. For the categorization of information, a similar approach was used. Therefore, the results were presented in a way that the experts could see the percentage distribution based on all the experts' opinions of the classification of information in specific categories in the following iterations. Similar to the evaluation of the importance of one kind of information, new categories (defined by the experts) have been implemented in the questionnaire for the following iterations. The redesigned questionnaire with the average values of the previous iteration was sent to the experts again, so that they could reconsider their opinion if necessary. This last step was performed repeatedly for three complete iterations and after it a final result of the Delphi Study with an aggregated group opinion was available.

Based on the approach described here, the Delphi Study was conducted over a period of 6 months and it was possible to gather a group opinion in terms of importance as well as in terms of categorization of information types in simulation studies.

## 5. Results of the study and further research

The following explanations show an overview and a summary of the results of the Delphi Study. For a better understanding, details on specific information types as well as details on only example categories are shown. The results presented generally refer to the evaluations from the third and final iteration of the questioning. From the 20 participating experts in the first iteration, 12 experts sent back completely answered questionnaires (response rate 60%). These 12 experts were asked again in the second iteration and eight questionnaires (response rate 66.67%) have been returned. This can be partially explained by schedule problems as well as by comprehension problems. In the third and final iteration of questioning, the eight responding experts from the second iteration and an additional four missing experts who answered already in the first iteration, but did not participate in the second iteration, were asked. Altogether, 10 completed questionnaires were obtained (response rate 83.33%) in the third and last iteration of Delphi Study.

To help understand the structure of the study, particularly concerning the design of the questionnaire, a section of this questionnaire is shown in Table 1. The section shows an example of the assessment of two information types by one expert. In terms of time the section shows the result at the end of the second round. Subsequently, all answers of the experts were prepared for the third round. This questionnaire was designed correspondent to the illustrated questionnaire. Only the questionnaire for the first round was designed in an easier way, because there were no results that could be shown to the experts. Not shown in the section is the possibility for comments, as well as the possibility to define omitted information types. These options were given to the experts after the evaluation of the information types gathered in earlier rounds.

[1]The ASIM (Arbeitsgemeinschaft Simulation) is an association dedicated to the promotion and development of modelling and simulation in the German-speaking area. As an expert committee ASIM is organizationally a part of the society for computer science (GI). Owing to the interdisciplinary composition of its members from various sectors of industry as well as applied research, it is the central node of a network of simulation users.

**Table 1** Example section of the Delphi questionnaire (2nd evaluation round)

| *ID* | *Object of evaluation* | *Overview* | *Evaluation* |
|---|---|---|---|
| 1 | Information on how to gather information for the simulation study. | 2nd round | 4 |
| | | Your answer 1st round | 3 |
| | | Arithmetic average of all experts | 3.6 |
| 2 | Information about the IT systems applied in the considered company. | 2nd round | 2 |
| | | Your answer 1st round | 3 |
| | | Arithmetic average of all experts | 2.1 |

Based on the 36 information types presented at the beginning of the study (see first 36 information types in Table 2), a total of 53 different information types could be identified by the end of the Delphi Study because of the previously described possibility for the participants to define additional information types. These 53 identified information types were evaluated for importance with an average value in a range from 1.8 to 5.0. Thus, none of these information types was considered as unimportant in principle (score 0) in its average value. Table 2 shows the information types that were identified in the order in which they were presented to the experts for evaluation. In this case, thematically similar information types in the table for evaluation were not listed side by side to ensure that no bias could arise for the following classification of these types into categories.

The information type, which includes '*Information about the evaluations that should be carried out at the end of the simulation study*' (No. 4 in Table 2) can be cited as an example for the evaluation of information types. This information type was rated with an importance of 5.0 (very important) by all experts, so it also has an average value of 5.0. It is directly related to the defined aims of the investigation and includes information on activities that need to be carried out in order to fulfil the objective target of the entire simulation study. Typical characteristics of this information type refer to staff utilization, buffer stocks or cycle times in the system considered. Depending on the object being investigated, these characteristics could be an essential measurement for evaluation in a simulation study.

'*General information about the company and the industrial sector*' (No. 14 in Table 2) can be mentioned as an information type that has been evaluated as less important (average value 1.8) by the experts. This information type includes information that is not absolutely necessary for conducting the simulation study. This information only provides a supplementary benefit by delivering information about tangential issues.

In total, the analysis of the answers for the evaluation of the importance of information types in simulation studies resulted in the distributions of average values shown in Figure 2. It turns out that over 50% of the evaluable information types were evaluated with a minimum average importance of 4.0. As already described, there has been no information type evaluated in average with an importance smaller than 1.0.

By analysing the scatter of the importance of individual information types, a more detailed evaluation of results can be made. It can be seen that this scatter was considerably reduced by the number of iterations. This aspect shows the principle of the Delphi methodology for consensus building. More specifically, this application is shown by reducing the scatter of an average of 3.2 rating points per information type in the first round, to 2.3 rating points per information type in the third round of questioning. Figure 3 shows the scatter in the evaluation of importance as a result of the findings of the last round of questioning. For this purpose the information types are sorted according to their evaluated importance. The figure shows the resulting mean value of the evaluated importance as well as the lower and upper limits for each information type given by different experts.

In comparison with the more important information types evaluated, one can see that especially the less evaluated important information types have a higher scatter. This can be explained principally by the heterogeneity of simulation studies, and in this particular case also by the various backgrounds of the experts. Accordingly, there are information types which are generally regarded as being particularly important. However, there are also information types which may apply as important only to a particular application of simulation. For other possible applications of simulation, last mentioned information types seem to be less important.

In contrast to the average value, the median shows that a greater orientation towards important information with a rating equal to 4.0 and above is available (approx. 68%). This can be avoided by considering the median. Finally, the Delphi Study shows that the identified information types have a relevance to simulation studies. In addition, it was possible to create a list of all relevant information in simulation studies based on the knowledge of the participating experts by giving them the possibility to define missing information types.

Regarding the classification of information types into categories, there was a numerically strong classification of information types in the five 'original categories'. Because of the expert's option to define new categories, there are

**Table 2** Information types and their significance

| *ID* | *Information type* | *Significance* | |
|---|---|---|---|
| | | *Arithmetic average* | *Median* |
| 1 | Information on how to gather information for the simulation study. | 3.9 | 4 |
| 2 | Information about the IT systems applied in the company considered. | 1.8 | 2 |
| 3 | Information about the period of investigation | 3.7 | 4 |
| 4 | Information about evaluations that should be carried out at the end of the simulation study. | 5 | 5 |
| 5 | Information about the focus of the simulation study regarding content. | 4.5 | 4.5 |
| 6 | Information about the individual goals of persons involved in the simulation study. | 3.2 | 3 |
| 7 | Information about persons involved and important contact persons of the simulation study, such as name, e-mail address, telephone number. | 4.6 | 5 |
| 8 | Information about necessary appointments during the execution of the simulation study, such as the review of interim results. | 4.9 | 5 |
| 9 | Information about who fulfils the tasks in the context of a working concept. | 4.3 | 4.5 |
| 10 | Information about the experiments to be executed as part of the simulation study. | 3.7 | 4 |
| 11 | Information on relevant stochastic processes of the system under consideration | 4.4 | 5 |
| 12 | Information on possible adjustments of the initially defined goals of the simulation study | 4.5 | 5 |
| 13 | Information about problems that exist with respect to the observed object of the simulation study. | 4.3 | 4 |
| 14 | General information about the company and the industrial sector. | 1.8 | 2 |
| 15 | Information about the appointments to the results and interim results meeting during the simulation study. | 4.6 | 5 |
| 16 | Information about the results of statistical calculations. | 3.9 | 4 |
| 17 | Information verifying the simulation model through a positive/negative balance of availability, utilization, throughput, throughput time, output, total availability. | 4.9 | 5 |
| 18 | Information (or data) on the system to be simulated (eg, controls, process sequence, material flow, layout, product lists, predecessor and successor lists, etc). | 4.9 | 5 |
| 19 | Information on requisite abstractions/detailing of the simulation model and the requisite activities. | 4.2 | 4 |
| 20 | Information about data structures such as lists or tables in the simulation model. | 2.4 | 2 |
| 21 | Information about available software and licenses relevant to achieving simulation study goals. | 2.7 | 3 |
| 22 | Information for checking (interim) results by consulting (with employees and managers). | 3.4 | 3 |
| 23 | Information about the completeness of the simulation model to validate the results. | 4 | 4 |
| 24 | Information on interim status and interim results of the simulation study. | 4.1 | 4 |
| 25 | Information about what data/information already exist in the considered companies performing the simulation study. | 4 | 4 |
| 26 | Information about the degree of automation used to build the simulation model. | 3.2 | 3.5 |
| 27 | Information about methods/tools and techniques which could be used for performing the simulation study. | 2.9 | 3 |
| 28 | Information about the order, number, combination and priority of experiments during the simulation study. | 2.5 | 3 |
| 29 | Information about the (interim) results that should be presented and their level of detail. | 4.2 | 4.5 |
| 30 | Information on the results of a comparison of simulation results with real data from the real system. | 4.4 | 4.5 |
| 31 | Information from customers about the acceptance or the confirmation of the (interim) results. | 3.9 | 4 |
| 32 | Information about the methods used for verification and validation during the implementation of the simulation study. | 3.5 | 3.5 |
| 33 | Information on compliance with the schedule for achieving the desired goals of the simulation study. | 4.1 | 4 |
| 34 | Information about the complexity and the expected effort of performing the simulation study. | 4.6 | 5 |
| 35 | Information about the feasibility and the range of results in a simulation of the observed area. | 4.5 | 5 |
| 36 | Information on the possible actuating and measured variables of a simulation model. | 4.5 | 5 |
| 37 | Information about the process in case of deviations from the project plan (eg delays, adjustments). | 4.1 | 4 |
| 38 | Information about the documents to be created during the simulation study (eg model description, protocols, presentation of results). | 4.1 | 4 |
| 39 | Information about already existing simulation experience from the departments involved. | 2.5 | 2.5 |

**Table 2** Continued

| ID | Information type | Significance | |
|---|---|---|---|
| | | Arithmetic average | Median |
| 40 | Information on general guidelines for performing simulation studies. | 3.7 | 4 |
| 41 | Information about the frequency of applying simulation (once, regular etc). | 3.4 | 3 |
| 42 | Information about the qualification of the staff involved in the simulation study | 3.3 | 3 |
| 43 | Information about shift models. | 4.2 | 4.5 |
| 44 | Information about the use of available information in existing models (eg pseudo code). | 2.6 | 3 |
| 45 | Information on the availability of the involved people and contact persons of the simulation study. | 3.7 | 4 |
| 46 | Information on the required input data (as well as the necessary quality of data) and the required granularity of input data to achieve the required quality of results. | 4.4 | 4.5 |
| 47 | Information about potential criteria that lead to the termination of the simulation study. | 4.1 | 5 |
| 48 | Information about the possibility of further use and transfer of the model built. | 3.8 | 4 |
| 49 | Information about constraints for the simulation study, eg financial reasons. | 3.89 | 4 |
| 50 | Information about prior knowledge of the customers in simulation. | 2.7 | 3 |
| 51 | Information about questions for the planned simulation. | 4.7 | 5 |
| 52 | Information about the budget for the realization of the found solution | 3.6 | 3.5 |
| 53 | Information about assumptions/constraints of the variant formation. | 3.8 | 3.5 |

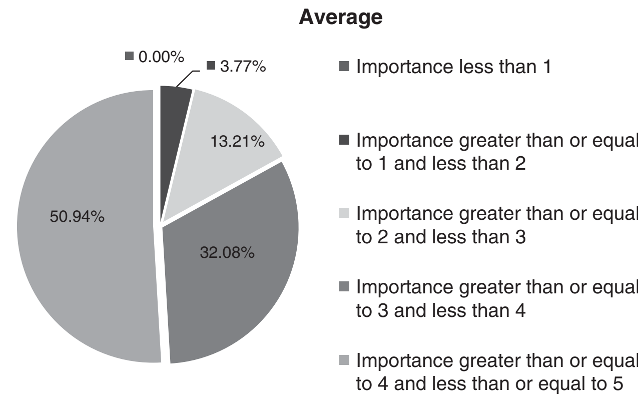



**Figure 2** Average for evaluating the importance of information types (own illustration).

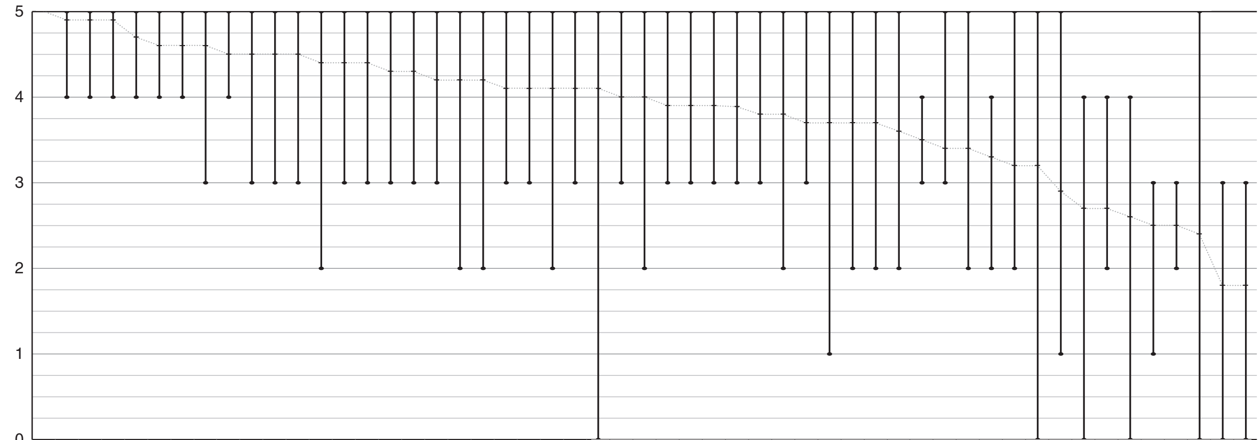
a total of eight categories. However, the percentage of the classification in the three additional categories was very low and the 'original categories' have been adjusted by the experts during the study so that they can be used as the basis for further research.

In principle, it was permissible to classify information types to any of the listed categories in the first and in the second iteration of the study. From the third iteration of questioning these multiple classifications were restricted to consolidate the expert's opinion so that the experts had to classify each information type in a maximum of two different categories.

The resulting classifications of information types were analysed for recognizable trends. In the Delphi Study, which is generally a suitable method to analyse trends in the different application areas (cf. Häder, 2009; Gregersen, 2011; Paetz *et al*, 2011), described in this article, a trend is defined when all the experts classified one information type to one category by more than two thirds (66.66%). In addition, based on the possibility of multiple answers, this classification must have this minimum of 66.66% of the expert's opinions for only one category. If such a trend was recognizable, this information type was assigned to that category.

Altogether, 84.9% of the 53 different information types could be classified in a category. In all, 7.55% of the information types could not be classified because there was no trend within the meaning of a clear classification to only one category. The other 7.55% of the information types were not clearly classified, because there was no two-thirds majority for at least one category. The defined categories and the number of the classified information types for the different categories can be found in Table 3.

A potential benefit of the results is to use these results as a basis to develop a methodology for assessing the influence of information quality on the result quality in simulation studies. For this, an essential step is assessing the quality of information. The identification of the 53 information types




| | Type 04 | Type 08 | Type 17 | Type 18 | Type 51 | Type 07 | Type 15 | Type 34 | Type 05 | Type 12 | Type 35 | Type 36 | Type 11 | Type 30 | Type 46 | Type 09 | Type 13 | Type 19 | Type 29 | Type 43 | Type 24 | Type 33 | Type 37 | Type 38 | Type 47 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| maximum | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 |
| minimum | 5 | 4 | 4 | 4 | 4 | 4 | 4 | 3 | 4 | 3 | 3 | 3 | 2 | 3 | 3 | 3 | 3 | 3 | 2 | 2 | 3 | 3 | 2 | 3 | 0 |
| average value | 5,00 | 4,90 | 4,90 | 4,90 | 4,70 | 4,60 | 4,60 | 4,60 | 4,50 | 4,50 | 4,50 | 4,50 | 4,40 | 4,40 | 4,40 | 4,30 | 4,30 | 4,20 | 4,20 | 4,20 | 4,10 | 4,10 | 4,10 | 4,10 | 4,10 |

| | Type 23 | Type 25 | Type 01 | Type 16 | Type 31 | Type 49 | Type 48 | Type 53 | Type 03 | Type 10 | Type 40 | Type 45 | Type 52 | Type 32 | Type 22 | Type 41 | Type 42 | Type 06 | Type 26 | Type 27 | Type 21 | Type 50 | Type 44 | Type 28 | Type 39 | Type 20 | Type 02 | Type 14 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| maximum | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 4 | 5 | 5 | 4 | 5 | 5 | 5 | 4 | 4 | 4 | 3 | 3 | 5 | 3 | 3 |
| minimum | 3 | 2 | 3 | 3 | 3 | 3 | 3 | 2 | 3 | 1 | 2 | 2 | 2 | 3 | 3 | 2 | 2 | 2 | 0 | 1 | 0 | 2 | 0 | 1 | 2 | 0 | 0 | 0 |
| average value | 4,00 | 4,00 | 3,90 | 3,90 | 3,90 | 3,89 | 3,80 | 3,80 | 3,70 | 3,70 | 3,70 | 3,70 | 3,60 | 3,50 | 3,40 | 3,40 | 3,30 | 3,20 | 3,20 | 2,90 | 2,70 | 2,70 | 2,60 | 2,50 | 2,50 | 2,40 | 1,80 | 1,80 |

**Figure 3** Scatter of the importance at the end of the Delphi Study (own illustration).

**Table 3** Assignment of information types into categories

| *Category* | *Type IDs* | *Number of classifications* |
|---|---|---|
| Information about the imaging concept (level of detail) and the required methodologies, tools, systems, and lists. | 2, 20, 21, 27, 32 | 5 (9.43%) |
| Information about the process, directly or indirectly concerned people, times and dates (organization). | 1, 6, 7, 8, 9, 15, 22, 33, 34, 37, 38, 39, 42, 45, 50 | 15 (28.30%) |
| (Strategic) information about tasks and goals as well as their changes and the principle approach of the simulation study. | 5, 12, 14, 35, 41, 47, 48, 51, 52 | 9 (16.98%) |
| Information on results and how to secure these results. | 4, 16, 24, 29, 30, 31 | 6 (11.32%) |
| Information about the simulated system with all the necessary model parameters and data requirements. | 3, 11, 13, 18, 25, 26, 36, 43, 44, 46 | 10 (18.87%) |
| *Double classifications* | *17, 19, 23, 40* | *4 (7.55%)* |
| *No trend* | *10, 28, 49, 53* | *4 (7.55%)* |

within the Delphi Study will form the basic framework for this purpose. As a result, there is no need to assess any information separately and the quality assessment can be done at the level of information types. To simplify the process further, it would even be possible to make the assessment on the level of the identified information categories.

The influence of the quality of an information type also depends on its importance in carrying out a simulation study. For this reason, the resulting evaluation of the importance of information types can be used as a reference and as a template for the development of a methodology for the analysis of influence.

Because of this additional research, which is part of a dissertation at the Department of Organization of Production and Factory Planning (University of Kassel), an evaluation of the influence of the quality of information is no longer an intuitive process based only on the experience of simulation experts. Rather, this approach offers the possibility for an objective and independent evaluation of simulation results taking into consideration the underlying information and its quality.

## 6. Conclusion

Based on the knowledge that information is an essential resource that determines the quality of simulation results, it is necessary to analyse which kind of information is generally relevant to simulation studies.

However, in the context of simulation studies no simple list of this relevant information currently exists. Furthermore, there is no evaluation of the different importance of different information for a simulation study available. This is why the Delphi Study described in this article was performed. The results of this study provide a list of 53 basic information types for simulation studies, evaluated on the basis of expert opinions with different importance. In addition these information types were categorized, which provides essential support for further research.

In the future, based on the list of relevant information types as well as based on their categorization, further research activities can start. One of the research objectives could be the described aspect concerning the evaluation of the influence of information quality on the quality of the results of a simulation study.

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*Received 1 March 2012;*
*accepted 14 February 2013 after two revisions*