Insights into the Practice of Expert Simulation Modellers

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ABSTRACT

In this study we report the result of an empirical study investigating simulation modelling practices and processes of expert modellers in business and industry. The results suggest that most of the participants do not have a clearly defined or a formal process for developing their models, rather a set of key steps or stages depending on certain contextual factors and personal style. A number of contextual factors such as the problem domain, the scope of the problem, the size and complexity of the model, may affect the way a modeller goes about developing his/her simulation models. Generally a three phased approach is identifiable which can be named as problem definition, model development, and model usage. Model documentation largely depends on model life, client requirement, and type of model being developed. Maintenance and reuse of model is generally not practiced, given most of the models developed are of short to medium term use; however, experience and knowledge is something that is reused.

Keywords: business process modelling, simulation modelling practice, simulation context, simulation modelling process

1. INTRODUCTION

We present the results from an interview study that investigates the practices of business process simulation modellers in order discover they underlying process of model development. Twenty expert simulation modellers selected from industry and academia described their simulation contexts and practices.

Business process modelling & simulation (BPMS) generally lacks a rich body of literature reflecting on the modelling and simulation practices of modellers in real world. Successful application of modelling and simulation may depend very much on the personal practices of a simulation modeller (Willemain 1994). A huge number of case studies and personal anecdotes of successful application of simulation in different areas of business and industry can be found in simulation and modelling literature, however, little can be found in these studies as to how these modellers go about developing their models and simulation.

Modellers in business and industry develop their models under a variety of constraints and contexts. The contextual factors may have an effect on the way modellers go about developing their models (Robinson 2002, Salt 2006). The problem domain, the scope of the problem, simulation language/technique/package used, the size and complexity of the problem simulated are some of the contextual factors which may affect a modeller's approach to model development. Therefore it is important to reflect on how simulation context and practice relate with each other.

Quite a few surveys have been reported in BPMS literature aiming to explore characteristics of modellers (Murphy and Perera 2001, Hollocks 2002), and practice (Melao and Pidd 2003, Cochran 1995), nevertheless, there is rare accounts of in-depth studies of modelling & simulation practice. These quantitative studies have provided useful indicators to understand characteristics of modellers and their backgrounds, nevertheless, these studies may not provide an in depth view of practice. One of the prominent in depth study of simulation modelling practice has been conducted by Willemain (1994, 1995), that explores the way expert modellers develop their models. Willemain (1994) studies the practices of expert modellers and suggests that practical guidelines for model formulation should be developed for novices in order to become experts. Foss et al (1998) reports a field study of industrial modelling process. Foss et al. (1998); interviewed 10 expert modellers and explored their process of simulation model development and proposed guidelines for improving simulation practice. This study empirically investigates as to how expert modellers develop their simulation models and how their context may affect their simulation practice.

We believe that investigating the practices of expert modeller will enable further understanding of simulation practice and underpin the simulation methodology research.

The paper has been organised in 6 sections. Section 2 gives an overview of the research methodology, Section 3 summarises study participants and their contexts. Section 4 discusses participants' simulation practice and processes, Section 5 provides a discussion on the results and Section 6 concludes the paper.

Table 1: Participants and modelling contexts

Summary of Education and Professional Roles					
Education summary	PhD Masters Bachelor	14 3 3	**Professional role summary**	Consultant (C) Researcher (R) C/R	9 5 6
Experience	Avg. Experience	8.5 years			

Summary of Model life, size, complexity, and Modelling Techniques			
Model Life	Short-term 8 (40%)	Long-term 2 (10%)	Long/Short-term10 (50%)
Modelling Technique	DE: 8 (40%)	SD: 3 (15%)	Both DE and SD: 9 (45%)
Size	Small: 3 (15%)	Medium: 14 (70%)	Large: 3 (15%)
Complexity	Low: 3 (15%)	Medium: 12 (60%)	High: 5 (25%)

Summary of Types of Models
Aims of models : Insights, cost and schedule, forecasting, Resource planning, allocation and evaluation Process improvement, Quality assurance, Understanding, Process performance monitoring and measurement, Process design
Application area: Process change, improvement, and optimisation, Planning, Technology adoption, Project management, Education and training, Project control and operational management
Problem domain: Safety control systems, Oil and gas pipelines, Mining, Supply chain and logistics, Airport processes, Call centres, Manufacturing, Financial services, Defence (weapons, vehicles), Telecom, Retail, Road and traffic, Health care, Software development processes, Scientific (physical, bioinformatics)
***Key**: C=Consultant, R=Researcher, DE = Discrete event, SD = System dynamics, HB = Hybrid models, SB = State based*

2. METHODOLOGY

This study follows a preliminary survey of 17 expert modellers (Ahmed et. al. 2008) which was an adaptation of Willemain's survey. Insights from this survey instigated our interest in exploring the context and practices of expert modellers in depth. The results from survey allowed construction of a framework of ideas, relevant to the context and practices of simulation modellers, explored in this study.

We wanted to study the context and practices of expert modellers in-depth and generally in a structured manner, therefore, we used semi-structured interviewing technique. Answers to the following research were explored with the participants:

***RQ1**: What are the modelling contexts of business process simulation modellers?*
***RQ2**: What are the modelling practices of business process simulation modellers?*

A pool of interview questions was prepared, consisting of some main open ended questions and several auxiliary questions which were to be asked depending on the flow of interview. A questionnaire consisting of open ended questions was sent to the participants a week prior to conducting the interviews. We also prepared an interview script document, which was used during the interview to ensure a generally uniform way of conducting interviews with all the participants.

We also conducted an intensive pilot study to evaluate the interviewing instrument. This pilot study was conducted in two phases; first, pre-testing the interview questions validity and second, piloting the interview sessions. In the pre-testing, four participants evaluated each question for its understandablity and relevance on an initial draft and questions were improved on the basis of feedback by participants. Piloting the interview sessions with four other participants to evaluate the research instrument helped assessing the appropriateness of the structure and flow of the interview questions. It also helped testing and improving interviewing approach and provided valuable practice for the main set of interviews. The use of audio recording equipment was also evaluated. Moreover, it helped determine the time necessary for interviews.

3. THE PARTICIPANTS & THEIR CONTEXTS

The participants in this study consist of both simulation practitioners and researchers. There are 20 participants in total coming from USA, UK, Germany, Spain and South Africa. Table 1 provides a summary of participants' contexts. A thorough discussion on participants' contexts has been provided in an earlier paper (Ahmed & Robinson 2007), however, here we will provide a summary of their contexts.

The participants consisted of three groups; researchers (R), consultants (C), and researchers cum consultants (C/R); inclusion of both groups gives an insight both into the industry and academia. Table 1 shows that there are 14 participants with a PhD, 3 participants with Master degrees, and 3 participants hold Bachelor degree. This suggests that the participants in this study are highly educated and most of them had some modelling education as part of their professional or research degrees. The average experience of the participants in simulation is 8.5 years. This suggests a high level of simulation experience amongst the participants.

The types of model developed by the participants have been classified with regard to their aims, application area, problem domain, size, complexity, and term of use.

Most the participants develop process simulation models to study, plan, control, and manage the issues of cost, quality, and resources as shown in Table1. Table 1 shows that they mainly develop simulation models that fall in the application areas of process improvement, process understanding, project planning and management, technology adoption, and project/process control and operational management. Moreover, the participant have developed simulation models in the problem domains of airport processes, passenger flow, cargo, logistics, supply chain management, mining, oil and gas pipelines, call centres, manufacturing, telecom, financial sector, banks, healthcare policy planning, defence, and software development processes.

Table also shows that most models developed by the participants are for short-term use, however, on rare occasions they have also developed models for longer term use. The model's life of use may have an effect on the practices of simulation modellers (Ahmed & Robinson 2007), which will be described in the upcoming sections.

Most of the participants have experience of working both with discrete event and continuous techniques. Only 3 participants have experience of using continuous simulation exclusively while 8 participants have worked exclusively with discrete event simulation. The participants use different tools for developing simulation models; Witness and Extend for discrete event and Vensim for system dynamics are the most popular tools amongst these participants. Participants claim that choice of simulation tool may have a positive or negative effect on the simulation practice of a modeller (Ahmed & Robinson 2007).

They mostly develop simulation models of small and medium size. Also most of the participants develop simulation models of low or medium complexity. Most of the participants also believe that simulation model size and complexity are related, i.e. the bigger the simulation model, the higher the complexity will be, however, some participants also noted that a small model may also be very complex depending on the nature on a problem (Ahmed & Robinson 2007).

4. SIMULATION MODEL DEVELOPMENT PROCESS

In this section we present an analysis of the simulation model development process of the participants. There are 35 themes identified from the interview transcripts which are relevant to simulation modelling processes. Each participant described his/her simulation modelling process at varying levels of detail. Each participant's simulation modelling process has been summarised in a process matrix in Table 2.

Most of the participants described their process in a linear fashion, emphasising that there is always a fair amount of iteration in their process. The main process activities described by the participants are problem communication with the client, defining simulation objectives and questions, problem understanding and analysis, definition of inputs and outputs from the simulation model, model design, construction, verification and validation, and experimentation.

Table 2 shows that some of the participants tend to use software engineering terms such as requirements, requirements analysis, basic and detailed design, and testing. S2 describes a spiral approach to simulation model development and S8 describes an evolutionary and iterative approach. S4, S5 and S10 describe a process similar to the waterfall model of software development, with steps such as requirements gathering, analysis, design, implementation, and testing (validation and verification). S7 said that he/she has a completely ad-hoc approach to simulation model development with no specific process steps. S3, S4, S5 and S9 described their process in much more detail than the others. S3 and S4 develop highly complex models and S5 develop large models; perhaps this could explain the detailed natured of their process. Also S3 and S4 have experience of working both with discrete event and continuous simulation. S11, S13 and S14 described their process in a highly detailed manner. S15 and S19 described their process at a very low detail.

In Table 2 we summarise findings about the simulation modelling process practice of the participants.

Apparently the simulation modelling process of the participants can be categorised into three phases as Problem Definition, Model Development, and Model Usage and Experimentation. Following we describe findings related to each phase and subsequently some other related themes.

4.1. Modelling Process Phase I: Problem Definition

1. Only three participants mentioned simulation user identification as a step in their process. The user can be the client or some other person in the organisation who needs results from the simulation study. They claim that establishing who the user of the simulation is very important to increasing confidence in the study results. This is because without close interaction with the user, a simulation study may not be of any value to its users. Moreover it is also important to identify the domain or subject matter experts with whom the simulation modeller may need to liaise during the model development.
2. Most of the participants indicate that the identification of simulation goals/objectives and simulation questions is one of their earliest steps in a simulation study.
3. Some of the participants used the term "requirements gathering" while talking about simulation goals and questions. This is perhaps because of their software engineering background.
4. Some participants (S7, S8, S12, S15, S20) do not spend much time on analysis and design, rather they identify simulation goals, gain a basic understanding of the problem and develop a simple and small simulation model straightaway, adding details as they go; a rapid approach.

Table 2: Simulation Modelling Process matrix of the participants

		S1	S2	S3	S4	S5	S6	S7	S8	S9	S10	S11	S12	S13	S14	S15	S16	S17	S18	S19	S20
	Phase – I: Problem Definition																				
1	Initial contact with client									X		X			X						
2	Problem communication									X		X	X		X		X				
3	Quick sessions with customer															X					
4	Simulation user/domain expert identification			X					X	X		X	X						X		
5	Setting goals	X	X		X				X	X		X	X	X	X		X				X
6	Questions	X			X		X	X	X			X	X		X		X		X		X
7	Requirements gathering		X		X						X			X							
8	Req. Validation				X																
9	Identify and define model inputs	X	X	X	X					X		X	X	X	X						X
10	Identify and define model outputs	X		X	X							X	X	X	X						X
11	System/problem understanding and Scope			X			X	X		X		X	X	X	X			X	X		
12	Requirements/process Analysis	X		X	X	X	X			X	X			X			X	X	X	X	
13	Data/ analysis			X	X		X							X							
14	Conceptual modelling											X		X							
15	Conceptual model validation													X							
16	Influence diagram	X		X						X	X			X			X	X			
17	Scenarios					X				X	X										
18	Technical feasibility check			X						X		X			X						
19	Build prototype								X	X		X			X		X		X		X
20	V&V of prototype								X	X							X				
21	Planning																X				
22	Tool selection						X	X										X			
	Phase-II: Model Development																				
23	Design		*X*		*X*	*X*					*X*					X					
24	Basic design				*X*	*X*					*X*							X	X		
25	Detailed design				*X*	*X*					*X*										
26	Construction/implementation	*X*	*X*	*X*	*X*	*X*	*X*	*X*	*X*	*X*	*X*	X	X	X	X	X	X	X	X	X	X
27	Model verification	*X*	*X*	*X*	*X*	*X*	*X*		*X*	*X*	*X*	X	X	X	X	X	X	X	X	X	X
28	Model validation	*X*	*X*	*X*	*X*	*X*	*X*		*X*	*X*	*X*	X	X	X	X	X	X	X	X	X	X
29	Calibration	*X*						*X*			*X*										
30	Testing					*X*					*X*										
	Phase III: Model Usage and Experimentation																				
31	Design Experiments		X	X						X			X	X	X			X			
32	Conduct experiment	X	X							X			X	X	X			X	X		X
33	Experiment results analysis											X		X	X						
34	Results presentation											X		X	X			X	X		X
35	Maintenance									*X*											

5. Most of the participants emphasised developing a firm understanding of the problem and capturing the scope of the problem. They talked about identifying the factors contributing to a system/process, understanding relationships between different factors/variables, and confirming those relationships with the client/user.
6. Some of participants emphasised that diagramming methods should be used to illustrate relationships between various factors. This would not only enhance problem understanding but also helps validating the problem understanding with the client.
7. Most of the participants say that identification and definition of inputs and outputs of a simulation model is very important and should be started in the earliest stages of a simulation study.
8. Two participants mentioned conceptual modelling as part of their simulation process. Conceptual modelling in the general simulation literature is said to consist of detailed analysis of the problem and designing the simulation. Analysis would be a detailed account of all the activities performed for problem understanding, identification of variables and the relationship between them. Robinson (2004) defines a conceptual model as, "*a non-software specific description of the simulation model that is to be developed, describing the objectives, inputs, outputs, content, assumptions and simplifications of the model*".
9. Four participants mentioned checking technical feasibility; i.e. whether simulation is an optimum tool for answering the problem. Moreover, simulation may not be needed to solve certain simple problems; in such cases simulation would prove to be rather an expensive solution.
10. S8, S9, S11, S14, S16, S18, and S20 emphasised on prototyping or building an initial simple abstraction of the whole problem explicitly talked about prototyping. These participants think that building a prototype and then getting feedback from the client helps validate problem understanding and also in checking the feasibility of simulation tool.
11. Only one participant, R6, mentioned planning as a step in the simulation modelling process. S16 generally developed very big and highly complex defence simulation models with a team of people; perhaps this is the reason that he/she mentioned planning as an important step.
12. Simulation tools can positively or negatively impact the efficiency and performance of simulation modellers, according to S6, S7, and S17. None of the other participants mentioned tool selection as a part of their process.

4.2. Modelling Process Phase II: Model Development

13. Only a few of the participants mention simulation model design as part of their process. Only six participants talk about design as a process step; three of these participants claim to be developing big and highly complex models. The results from our preliminary survey (Ahmed et. al. 2008) indicate that simulation model design is considered to be an issue, however, only a few participants in this study indicate that they do model design any formally. One possible explanation, as mentioned by S2, that the nature of simulation modelling does not require to devise a design prior to constructing the model; because most of the time in the early stages of modelling, neither client nor modeller understand the problem for which the model is to be designed; therefore it is difficult to design a model for which requirements are not clear. Another possible explanation could be that most of the simulation projects developed by these participants are small or medium which take a few days, weeks or months to develop; for such small projects as S8 says, it is not feasible to spend too much time on formally designing the simulation model.
14. All participants talked about building or constructing the simulation model using some simulation tool or programming language. Verification of the model is performed as the model is constructed. Most of the participants say that the whole simulation should not be constructed in one go, rather the validation of the model with the customer should be performed as parts of model are completed. During verification or validation, the modeller may discover some bug or problem with the model and may have to go back to develop further understanding of the problem. Almost all the participants emphasise that a modeller must provide sufficient comments in code or comment boxes while developing the model. This is crucial to understanding the model in case the modeller or some other person has to change the model at some later time.
15. Most participants consider validation and verification as equivalent to evaluation. Evaluation is driven more by customer satisfaction than any other factor. Moreover, some participants refer to model validation and verification in numerous ways such as testing, calibration and validation and verification.

4.3. Modelling Process: Phase III: Model Use and Experimentation

16. Most of the participants explicitly mention experimentation as part of modelling process. They describe that designing the experiments, analysing the results and presenting the results to the client are important tasks for conducting experiments with the simulation models.

4.4. Client contact and rapid development

17. Most of the participants emphasise heavy client contact. It is important to note that those who have emphasised heavy client contact are consultants or

researchers cum consultants. This is perhaps because in a research environment there is usually no client; therefore, the researchers do not mention heavy client contact as an important part of their process.

18. Most of the consultants indicate that in the commercial world it is very important to deliver a solution to the client very *rapidly*; because processes have to be adapted according to changing business need. If a simulation study takes months or years to deliver the results, it may not be of use to the client because during that time the business would have changed even further. Moreover, when the client is spending money on a simulation study, he/she wants to see the results instantly. Therefore, a simulation modeller must involve the client heavily and adapt his/her modelling process according to the client needs in order to deliver the results and recommendation quickly.

4.5. Individual Nature of Simulation Practice

19. All the participants say that they typically develop simulation models alone. However, they have to interact with the client, model users or the domain experts to understand the problem and collect data. Most of the participants say that sometimes they have worked and collaborated with other modellers; however, it seldom happens that they work on the same model concurrently. Only S16 says that he has worked and managed simulation model development where multiple people worked on the same model. However, in that case the project was an enormous defence simulation on which around 200 people worked. In other cases, as for instance S2 and S10 say, they worked with other modellers in a managerial role. S5, S9, S10, S11, S12, S13, say that they have worked on simulation projects in teams; however, in such situations roles such as simulation modeller, data collector, and process-mapper/system-engineer were well defined.
20. The participants give different reasons as to why simulation modellers tend work alone on a simulation study. One reason is that the nature of the simulation problems and the nature of modelling itself that do not require many people to work on the same project. Having more than one person introduces a time overhead because all the people involved have to have a similar level of understanding; S12 says this makes a project inefficient. S13 and S14 believe that having more than one person developing the same model introduces the problem of version/modification control and integration. In the view of S12, S15, and S16, the biggest problem in teamwork is the communication between different team members. S16 states that communication becomes even more problematic if the team members come from different educational and professional backgrounds.

4.6. Documentation practices

21. Most of the participants think that the best documentation for a simulation model is to put comments in the code or the comment boxes provided by the simulation tool rather than producing formal documents.
22. As shown in Chapter 6 (Table 6.10), most of the participants say that simulation goals and objectives should be clearly stated in the documentation (in comments or in formal documents) and be agreed upon with the client. However, a few of the participants also think that the scope of the model should also be defined in the documentation.
23. Some of the participants recommend that model inputs and outputs should also be defined so that the model can be well understood in future if needed.
24. Some of the participants think that the relationships between data items (inputs and outputs) should also be documented along with an influence/process diagram or using some other diagram methods. An overview of model structure or model working is also necessary to understand the model.
25. Most of the participants say that they produce reports or presentations of the simulation results which are presented to the client. These reports or presentation include the report of experiments, the scenarios and assumptions under which experiments have been run, analysis of results and recommendations from the analysis.

4.7. Others

26. Model reuse for a similar problem is not important for most participants. This is because they think that a model developed at one point in the past may be not depict the real world as it is now; as R3 says "*the business changes so much that the objects become out of date; I wonder if they are updatable*". However, some of the participants mention that the experience and learning gained from simulation projects is reused in subsequent projects. This finding is similar to what is found in literature that reuse in simulation is difficult therefore not much practiced (Robinson et al. 2004). Two of the participants, S4 and S6, mention that they reuse parts of their existing models. However, some participants said that it is the experience that is reused in subsequent simulation projects.
27. Majority of the participants do not emphasize simulation model maintenance. Only S9 explicitly mentions maintenance as part of the process; no one else discuss maintenance as part of their process. This is perhaps because majority of the models developed by the participants are of short-term use.

5. DISCUSSION

These results provide a general picture of a model development practice of the participants and the type models they develop under a variety of contexts.

The results indicate that most of the participants develop their models alone supporting the literature finding of Robinson (2002); however, for relatively larger projects a number of people may be working in different aspects such as problem understanding, data collection, model construction and validation and verification.

Most participants do not produce design prior to constructing their models. A possible explanation as mentioned by one of the participant is that the nature of simulation modelling does not require to devise a design prior to constructing the model; because most of the time in the early stages of modelling, neither client nor modeller understand the problem for which the model is to be designed; therefore it is difficult to design a model for which requirements are not clear. Another possible explanation could be that most of the simulation projects developed by these participants are small or medium which take a few days or weeks; for such small projects as S8 says, it is not feasible to spend too much time on formally designing the simulation model. However, for large models designing prior to model development and adapting the design during development is a must

Maintainability of models is not an issue for majaority of our respondents; however maintainability will inevitably become an issue if these models are to be capable of being evolved so that they remain useful in the long term. Our literature review suggests that the maintainability of models has not been given much attention in the general simulation literature; similarly in this study only a few participants indicate that they are concerned about maintainability. Maintenance and documentation are low priority issues. Another potential reason could be that perhaps the simulation models developed are too small (though they say they mostly build medium sized models as we have no agreed measure of size); or large but conceptually too simple to be documented and maintained. Another reason could be that most simulation models may not be used in the long term, therefore documentation and maintenance is not a problem. The participants believe that extent of documentation and maintainability varies in each individual case depending on the contextual factors such as client requirements, budget, time, expertise, and simulation model size and complexity. Issues of simulation model documentation and maintenance are also seldom discussed in the general simulation literature. Foss et al. (1998) say that most simulation models are poorly documented and are therefore rarely reused. The models evolve and are redefined over the period of time, and the managers who use the models may change their minds about priorities. Foss et al. (1998) further state that poor documentation makes it very hard to maintain the models. However, it is generally believed that reusing simulation models is difficult and less cost effective than building a new one from scratch (Taylor et al. 2004, Robinson et al 2004). On the other hand, the importance of maintenance, reuse, and documentation has been highlighted by Gass(1987) for large scale models.

Most of our participants also suggest that their models are rarely reused, however, the participants from military simulation background say that they emphasise model reuse. This finding supports the view of Salt (2006) where he suggests that defence modellers are obsessed with reuse while civilians do not bother reusing their models. One of the main reasons suggested by the participants is that reusing a simulation model is difficult; because most often simulation model represent a reality in business process at a given time but as the time passes the reality changes therefore an old model of that reality is of little use after the reality changes. However, the knowledge and experience gained from an old model can be reused in a new project. A similar view is held by the authors in (Taylor et al. 2004), Robinson et al 2004).

Gass (1987) suggests that the evaluation of models encompasses both validation and verification activities along with an assessments of the models' quality, usability, and utility. However, the results of our study suggest that this form of evaluation does not have a formal position in the simulation modelling practice of our participants. In general, simulation modelling literature seems to emphasize validation and verification activities; therefore, most possibly modellers consider this to be equivalent to evaluation. However, the extent of evaluation largely depends on contextual factors such as requirements. Another reason for not conducting a holistic evaluation by our participants could be that most models are used by themselves and results are provided to the client. Therefore, evaluating models in the aspects other than validation and verification is not of importance. However, if a model is to be handed over to the client; perhaps, evaluating usability and documentation is given some conscious consideration.

The results from this study also suggest that majority of the participants in this study don't seem to be using a highly defined formal process framework for their simulation modelling practice. However, most of them seem to have some specific steps, perhaps, unconsciously infused in their simulation modelling practice.

Simulation modelling in commercial context involves people, technology and tools. A well-defined process is believed to provide a framework where tools, technology and people collaborate, to enhance productivity and quality (Humphrey and Kellner 1989). Humphrey (1997) states that a good process brings discipline in human activities and improve the quality of software. It is the process that can effectively help engineers to produce high quality products, with reduced time, and control over cost (Cugola & Ghezzi 1998). This suggests that a good simulation modeling process may also improve quality and increase the productivity. However, it is rare to find such studies in simulation modelling literature where relation has been drawn between simulation model quality, modeller's productivity and use of a disciplined process.

On the other hand, Shannon (1975) says that simulation modelling is both art and science; producing art needs creativity (Kneller 1965), therefore simulation modelling needs creativity. Many simulation modellers believe that simulation is a creative accomplishment and if it is constrained by a process, creativity may suffer (Powell 1995). Paul et al. (2003) says, *"One can instantly see that fixed structure to develop simulation models will not be able to cope with all the situations at all times"*. This suggests that consider the context of a simulation modellers is important for applicability of a simulation modelling process.

Simonton (2002) suggests that creativity can be considered a constrained stochastic process; that is creativity is not completely random or stochastic, rather loosely bound in the rules of the domain for which creativity is needed. Johnson-Laird (1988) says that there can be many criteria of creative processes on which a creator may rely; some of those criteria will be common to many practitioners while others may depend on individual aptitude and style. This suggests that creative process does not consist of only stochastic random activities but there is some structure in the creative process. Ferguson et. al. (1997) suggest why discipline is needed alongside creativity:

> *"In most professions, competent work requires the disciplined use of established practices. It is not a matter of <u>creativity</u> versus <u>discipline</u>, but one of bringing <u>discipline</u> to the work so that <u>creativity</u> can happen."*

However, it seems that generally the simulation modellers are more interested in the end product and less in the process of creating that product. In simulation, where the world is driven by time constraints, commercial pressures, and competition, weakness in the modelling process may bring up many issues. Therefore, Gass (1987) suggested:

> *"We need to get away from the crutch that modelling is an art. Guidelines need to be proposed, methodologies for validation and evaluation need to be formalized and applied; and the concept that modelling is a profession with standards must be brought into education and on-the-job training activities of the coming generation of analysts."*

Eriksson (2003) suggest that a model's quality is questionable if it is constructed without a disciplined approach. It can be argued, therefore, that the creative principles of simulation modelling can be incorporated in a disciplined framework for simulation model development. A disciplined simulation modelling process that provides room for creative aspects of simulation is likely to produce good simulation models efficiently. Therefore if a process consolidated from real world simulation practice of expert modellers may provide discipline for productivity and quality and liberty and flexibility for creativity.

A number of simulation modelling processes have been reported in the literature for example Robinson (2004), Law and Kelton (2000), Shannon (1998), Nordgren (1995), however, they are based on author's personal experience of simulation model development. No such process has been reported in the literature that entails a simulation modelling process based on an empirical study of expert modellers' contexts and practices. It would be interesting to consolidate a process from real world practices of expert modellers and compare it with the processes reported in literature.

6. CONCLUSION

Studying the simulation contexts and practices of exerts helped understanding the way they develop their models modellers. Most of the participants do not seem to have a very well defined and a formal simulation modelling process. However, most of them seem to have some key steps or stages in their process of simulation model development. Generally a three phased process has been identified from the participants which can be named as problem definition, model development, and model usage. This study identifies some general trends in the simulation model development practice of the participants. It would be hard to generalise the results across the business process modelling and simulation community, however, it gives us some indication as to how people develop their models when their models are small/medium and their model's complexity is low/medium and when models developed for short-term use.

This study does not provide a uniform view of simulation practice in business and industry but some trends and indications on which future studies can be built to further underpin our understanding of the simulation practice real world. Conducting studies in each niche (e.g. defence, manufacturing, healthcare, retail, logistics etc.) of simulation modelling will help further understanding the state-of-the-art and state-of-practice in discipline specific area. Moreover, in-depth studies of various aspect of simulation modelling process (e.g. problem understanding, model design, documentation) will help understand and improve simulation practice. Furthermore, the findings from this study also encourage us to consolidate a simulation modelling process based on the empirical data collected from expert simulation modellers, which will be reported in future publications.

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