Implementation of the virtual teamworking concept into the simulation project life-cycle.

BANASZAK, Jakub.

Implementation of the Virtual Teamworking Concept into the Simulation Project Life-Cycle

Jakub Banaszak

A thesis submitted in partial fulfilment of the requirements of Sheffield Hallam University for the degree of Doctor of Philosophy

September 2004

Preface

This thesis is submitted to the School of Engineering of Sheffield Hallam University for the degree of Doctor of Philosophy.

I would like to express my deepest gratitude and appreciation to my supervisors Dr. D.T.S. Perera and Dr D.R. Clegg (School of Engineering) for their guidance, help and constructive criticism during the course of this study. I would like to thank my family and friends, in particular to my wife Agnieszka for her patience and support. I would also like to thank my colleagues and administrative staff within the School of Engineering, and the Research Office for their help and support.

The results obtained during the course of this research are the best to my knowledge and original, except where reference is made to the work of others.

J. Banaszak

January 2004

Abstract

Simulation is a powerful tool that allows producing the best solution for a variety of design and operational issues in manufacturing systems. It provides the ability to assess the impact of various solutions without interfering with the real system. Applying simulation in the decision making process can significantly decrease the cost and risk of implementing a new solution, and at the same time speed up the process of analysing and finding the optimum solution. However, simulation projects usually are complex, and involve a number of people in the model's developing process. The simulation team is usually formed with specific roles for team members to play, such as project leader, model builder, data provider, customer, consultant, etc. However, the globalisation of business operations means that individuals involved in a large multi-site simulation project may be physically dispersed across the organisation and the world. For example, simulation experts may be based in one location and their service may be offered to business units scatted across the globe. This makes more difficult to collocate all project participants in one place at the same time and consumes extra effort, time and cost. Applying a virtual team methodology, supported by the modern Internet-based communication technologies, can overcome the described problems - reduce cost and project time in a large multi-site simulation study. This research investigates the implication of employing the virtual team concept to the simulation team, collaboration process and quality of project output. The analysis introduces the framework for creating the virtual simulation team and two step methodology with short, medium and long recommendations proposed. Then the developed methodology is validated by empirical experiment and simulation experiment. However, in order to carry on the real life experiment a WWW-based application to support the virtual simulation team was developed, and applied in the collaboration process. The experiments positively validated the methodology and provided data to check and optimise the developed application. The study is concluded by discussion of the final research results and future work.

Introduction

Simulation is a powerful and well established tool that has the capability of producing the best solution for a variety of design and operational issues in manufacturing systems. It provides the ability to assess the impact of various solutions without interfering with the concerned real system. Law and Kelton (1991) argue that the simulation can significantly decrease the cost and risk of implementing a new solution, and at the same time speed up the process of analysing and finding the optimum solution.

Typically, simulation projects are complex, design to tackle a specific situation or problem, and involve a number of people in the developing process. The simulation study requires cooperative work and inputs from all parties involved in. The simulation team usually is formed with the specific roles for team members to play such as project leader, model builder, data provider, customer, consultant, etc.

However, the globalisation of business operations means that individuals involved in a large multi-site simulation project may be physically dispersed across the organisation and the world. For example, simulation experts may be based in one location and their service may be offered to business units scatted across the globe. The different locations of parties involved in a simulation project implicate time and cost consuming travelling operations to meetings and back, which not add value to a project. In order to eliminate the waste in a process of a simulation model development there is a call for applying the modern Internet-based communication technologies in the simulation teamworking.

The development in communication technologies has significantly affected the way that modern businesses work. In recent years, companies have successfully deployed the Internet based technologies to improve their business function as well as expand technological systems. The enterprises IT systems have been integrated with Internet technologies to improve the gathering and distribution of business information, and apply across the enterprises to communicate day-to-day activities.

The concept of teamwork, which became an important key to business innovation in the last two decades, also has evolved to the concept of virtual teamwork. Jennings (1997) defines a virtual team as a group of people who collaborate closely even though space, time, and organisational barriers may separate them. The virtual teamworking involves the continual use of information technology to support team activities such as setting clear goals, co-ordinating and negotiating with others, exchanging information, planning and managing the work process, and many others. The key characteristic of a virtual team is that there is no need for physical co-location of team members; instead modern communication technologies enable geographically dispersed team members to function as a co-located team.

The rapid expansion of the Internet has drawn the attention of academics, practitioners, and vendors involved with simulation. Special conferences have been organised (like for example WEBSIM), and a number of projects investigate the implications of Web, as well as developing new applications. It also appears that virtual teamworking concept can be applied into a simulation team. This eliminates the need for face-to-face meetings; interactions between team members are managed using modern communication tools enabling them to operate as a co-located team. In author's opinion it should also reduce time waste and cost produced by working in traditional simulation team in the new global market.

The successful transition from the traditional simulation team into virtual simulation team requires developing a methodology and procedures. However, reported guidelines and methodologies for setting up virtual teams are primary targeted at general business function, like Lipnack and Stamps (1997) or Duarte and Snyder (1999) publications. The engineering approach presented by Bal and Teo (2001), Orsak and Etter (1996); or IT application presented by Edwards and Sridhar (2003) cannot be simply applied in a simulation project. Considering different characteristics of the simulation project, which mainly is the development of a computerised simulation model; in authors opinion it is required to develop a methodology for setting up a virtual simulation team.

The project investigates the implication of virtual teamworking on a simulation project that it is concluded by the proposition of a new methodology for creating and maintaining virtual simulation team. The proposed methodology has guidelines to follow to establish from a group of people with different priorities and background an efficient and creative virtual team.

In order to examine the proposed methodology two validation methods were developed:

1. Analytical methods - Simulation models have been applied to compare effectiveness of different collaboration scenarios in a simulation project.
2. Empirical methods - Following the recommendation presented in the previous chapters a virtual team has been created to confront a real problem using simulation models and the developed methodology.

However, the empirical experiment required the building of a support application that could be used as the communication medium in the daily base collaboration process. During the development process emphasis was put on such factors as cost, ease of maintenance, user-friendliness, communication and data transfer. The created application uses the standard WWW client-server technology with a support database and link to simulation software, which allows the project participants to cooperate by using one of the popular Web-browsers.

The aim of this project was to investigate implications of applying the virtual teamworking concept into simulation project life-cycle. The study was focused around five research questions, which were generated by literature review and survey's results:

(1) How can the Internet based solution be applied in the life-cycle of simulation project in order to improve efficiency of simulation team?
(2) How do we establish a virtual simulation team?
(3) How can we apply the virtual teamworking concept into the simulation project life-cycle?
(4) What technology should be used to support the virtual simulation team?
(5) What are the implications of virtual teamworking on a simulation project?

As the result of this study the new methodology for establishing virtual simulation team was developed and validated. The methodology is based on the proposed new framework for effective virtual simulation teamworking

Chapter 1 in its first part introduces the simulation concept, rules and life-cycle. The advantages of team driven structures are presented and the typical structure and members of the simulation team are illustrated. The last part describes the implication of Internet technologies on simulation, which concludes in the first research questions about the consequence of the development of Internet technologies on the simulation project. In this chapter also a modern communication and collaboration technology is introduced, and technology selection factors discussed.

Chapter 2 presents the results of the survey carried out between the simulation practitioners to obtain their opinions concerning the implication of the Internet's boom on the simulation. The results help to answer the first research question and focus interest in merging the virtual teamwork concept with a simulation project team. That observed trend drives to establish the followed research questions about the implication of virtual teamworking on the simulation, methodology for establishing the virtual simulation team, and necessary support technology.

Chapter 3 introduces the concept of the virtual team, its characteristics, types and critical success factors. The potential benefits of virtual teamworking are also discussed.

Chapter 4 emphasises the need for developing the methodology for creating the virtual simulation team. The influential factors are discussed that drives the development of the framework for effective simulation virtual teamworking. The proposed methodology is presented and an implication on the simulation project discussed. At the end the methodology's validation process is proposed.

Chapter 5 introduces the development process of a Web-based application to support the simulation virtual team. The chapter follows through the whole process from the set up of the objectives, design, building, testing, to the final revision.

Chapter 6 presents the outcomes of applying virtual teamworking into the simulation project. To evaluate the methodology the problem was stated, the virtual simulation team formed and collaboration between participants was obtained by the developed application. The data collected during the project was used to validate the methodology and the technology.

Chapter 7 reviews the process of the analytical revision of the virtual teamworking in the simulation project. It describes the simulation analysis carried out to compare the traditional team concept with the virtual one. The results are presented and discussed.

Chapter 8 discusses repercussions of virtual teamworking on the quality of the simulation project. The concept of quality in simulation project is introduced and the possible implication of communication technologies investigated.

Chapter 9 contains an argument about the consequences of using the Internet technologies on the knowledge management. The process of gathering, distribution and access to knowledge sources are discussed. The implications of applying a virtual simulation teamworking on the knowledge management are presented.

Finally, Chapter 10 presents results and outcomes of the research. The final conclusions are presented and future work proposed.

1 Literature Review

1.1 Introduction

This chapter presents a background and history of simulation technology by a review of the literature. It presents documented approaches to the development of simulation models and simulation model life cycles. It also describes rules for the members of the simulation project team. This section is followed by a review of documented impact of the Internet technologies on the simulation techniques and project. The chapter concludes by describing the focus of this study and the resulting first research question, which is answered in the subsequent chapters of this thesis.

1.2 Simulation project

Simulation is a tool that allows the creation of a model of the system, which mimics reality. It can be executed on a computer machine to enable experiments to be conducted with the aim of studying the behaviour of the system with different variables affecting it. Moreover applying a computer to calculate the simulation model allows us, in a relatively short time, to observe and predict the behaviour of the system over the long period of time. The impact of a change in examining system factors can be monitored quickly and easily, enabling managers to explore a range of options without impacting on the system itself (Robinson 1994).

However, in the first place, the simulation analysis requires the development of some kind of model, which becomes the abstraction of the system. The model has to reflect the system with accuracy and methods adequate to interaction in it. In the next step a series of experiments are conducted where the variables in the model are changed to reflect the intended changes to the system. The analysis of the results will help to choose the most acceptable and profitable solution.

1.2.1 System and modelling paradigm

The purpose of the simulation project is to understand the relationships between system components or to predict how it will operate under a new policy. Banks and Carson (1984) pointed out that it is sometimes possible to experiment with the system itself, but this is not always possible or practical. For example, a new system may not yet exist, or be at the design stage, playing with system may be impossible, unwise or too expensive (ex. air traffic system).

Schmidt and Taylor (1970) define a system as a collection of entities e.g., people or machines that interact together toward the accomplishment of some logical end. Banks (1984) describes a system as a group of objects that are joined together in some regular interaction or independence toward the accomplishment of some purpose. However Law and Kelton (1991) indicate that in practice, the system in question depends on the objective of the simulation study and they represent the system stage as being a collection of variables necessary to describe a system at a particular time.

1.2.2 Types of simulation models

A simulation project involves building a model of the system to be studied, which Banks and Carson (1984) defined as a representation of a system for the purpose of studying the system. Mihram and Michram (1974) pointed out that a model is not only the substitute for a system, but it is also a simplification of it. On the other hand, the model must be adequately detailed to permit proper analysis and valid conclusions to be obtained about the real system. Robinson (1994) concluded that the basic rule is to include in a model the minimum amount of detail required to achieve the project's objectives.

According to Pidd (1992), there are two types of models – physical and mathematical. Physical or iconic models are usually the physical structure that represented the real system at reduce scale (For example, the model of the aircraft in the wind tunnel.). However, the mathematical models use symbolic notation and mathematical equations to represent a system.

Simulation models can be further classified as being static or dynamic, deterministic or stochastic, and discrete or continuous. A static simulation model represents a system at a particular point of time while a dynamic simulation model represents a system as it changes over time. A simulation model that does not contain random variables is classified as deterministic. While a stochastic simulation model has one or more random variables as inputs.

Systems can be also categorised as discrete or continuous. Generally a discrete system is one in which variables change only at a discrete set of points in time, but a continuous system is one in which the variables change continuously over time. Law and Kelton (1991) resumed that only a few systems are wholly discrete or continuous, but since one type of change predominates for most of the system, it is usually possible to classify a system as being either discrete or continuous. They also focused on the fact that the objectives of the simulation project strongly determine the choice of simulation techniques.

1.2.3 Purpose of using the simulation

Banks and Carson (1984) presented a number of reasons why it may be preferable to carry out experiments on a model rather than directly on the real systems:

1. Simulation allows the study and experimentation with the internal interactions of a complex system, or of a subsystem within a complex system.
2. Informational, organisational and environmental changes can be simulated and the effect of these alterations on the model's behaviour can be observed.
3. The knowledge gained in designing a simulation model can be of great value towards suggesting improvement in the system under investigation.
4. By changing simulation inputs and observing the resulting outputs, valuable insight may be obtained into which variables are most important and how variables interact.
5. Simulation can be used as a pedagogical device to reinforce analytic solution methodologies.
6. Simulation can be used to experiment with new designs or policies prior to implementation, so as to prepare for what may happen.
7. Simulation can be used to verify analytic solutions.

1.2.4 The benefits of using simulation in industry

Robinson (1984) describes the simulation as one of the most powerful operational research techniques with potential benefits such as:

- Risk reduction
- Greater understanding
- Operational cost reduction
- Lead time reduction
- Faster plant changes
- Capital cost reduction
- Improved customer service

These benefits were realised by the deployment of simulation to support the application presented in Table 1-1(Tye 1999).

Base = 65 Current/Past Users	%
Plant Layout and Utilisation	77
Analysing Material Control Rules	66
Analysing Required Manning Levels	65
Short Term Scheduling and Loading	60
Capital Equipment Analysis	52
Line Balancing	51
Inventory Evaluation and Control	49
Information Flow Analysis	40
Process Definition and Analysis	35

Table 1-1 Deployment of simulation in industrial application (Tye 1999)

Cohran et al. (1995) conclude that the most common application for simulation in US industry is design (facility design, system development and design), closely followed by research (product development, industry modelling) and then scheduling (shop floor workflow analysis, and prioritising).

1.3 Procedures for conducting a simulation project

A simulation process life cycle has been documented by a number of practitioners since the early stage of the technology. This section details two of them: Law and Kelton's procedure, and Balci and Nance's procedure. However it must be mentioned that other authors such as Banks and Carson (1984), Robinson (1994) or Gass (1987) also had presented their approaches.

1.3.1 Law and Kelton's procedure

Law and Kelton (1991) proposed a series of twelve steps that compose a typical simulation study (Figure 1-1). They state that a simulation study is not a sequential process, but as a project progresses, it may be necessary to return to earlier steps as a greater understanding of the system is gained.

Steps of a simulation project life cycle

1. Formulate the problem and plan the study. This step involves setting up the objectives of the study and development of the plan and schedule, which describes the required number of people and time for each aspect of the project.
2. Collect data and define a model. If the system exists, the function of this step is to collect data to specify operating procedures and probabilities distribution for random variables used in the model. If the system is in design stage the data must be estimated from the project assumption or other possible sources.
3. Valid? The authors believe that validation should be carried throughout the entire project. However, they propose that there are a number of points during the study where validation is particularly appropriate and essential. They pay attention to the concept of model validity and credibility to itself and the decision-maker. To achieve validity and credibility of the model, it is important to involve the decision-makers and model end-user on regular basis.
4. Construct computer programme and verify. The modeller has to make a choice between programming a model in a general-purpose language or a simulation language.
5. Make pilot runs. Pilot runs allow the modeller to conduct a process of analysis of input data to determine the accuracy of input data and to compare the output data to values from the real system.
6. Design experiment. To evaluate different system scenarios, it is necessary to design a series of experiments to test the system. The authors note that often, a complete decision regarding the number and type of experiments can be made at this stage, but data from experiments may generate additional experimental requirements.
7. Make production runs. In this stage the model is run to generate performance data for each experiment
8. Analyse output data. The results from the previous step are analysed using statistical methods. Confidence intervals can be constructed and data from different systems can be compared.
9. Document, present, and implement results. The assumptions that go into models and the computer program itself should be documented. Proper project and model documentation allows the re-use of the model in a future study.

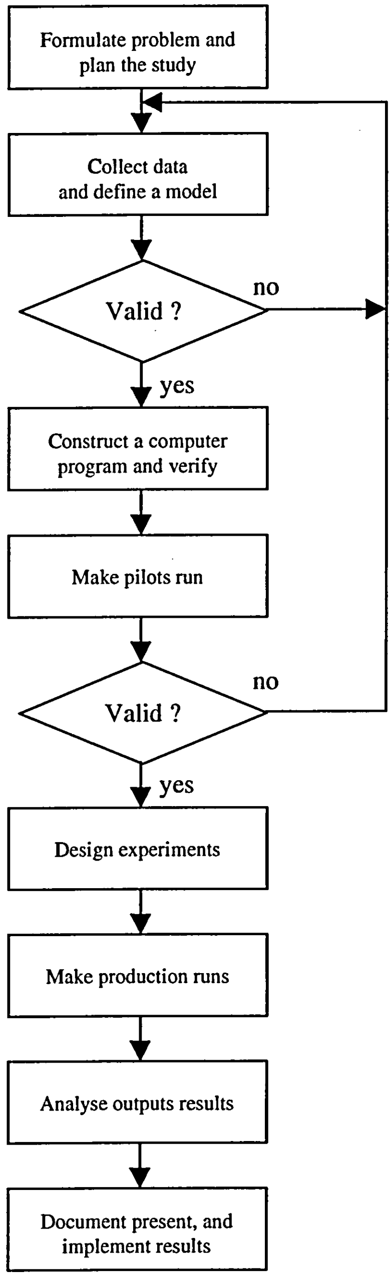

Figure 1-1. Steps in Simulation Project (Law and Kelton 1991)

1.3.2 Balci and Nance's procedure

Balci and Nance's simulation process procedure (Figure 1-2) consists of ten phases (Balci and Nance 1990), each phase representing an outcome of the process, indicated by the arrows connecting each phase. They pointed out that the simulation process life cycle is not a sequential process, but reverse steps may be taken when errors occur. They also dealed with issues concerning validation and verification at various stages of the project, in particular identifying appropriate validation and verification techniques for the different phases of the project.

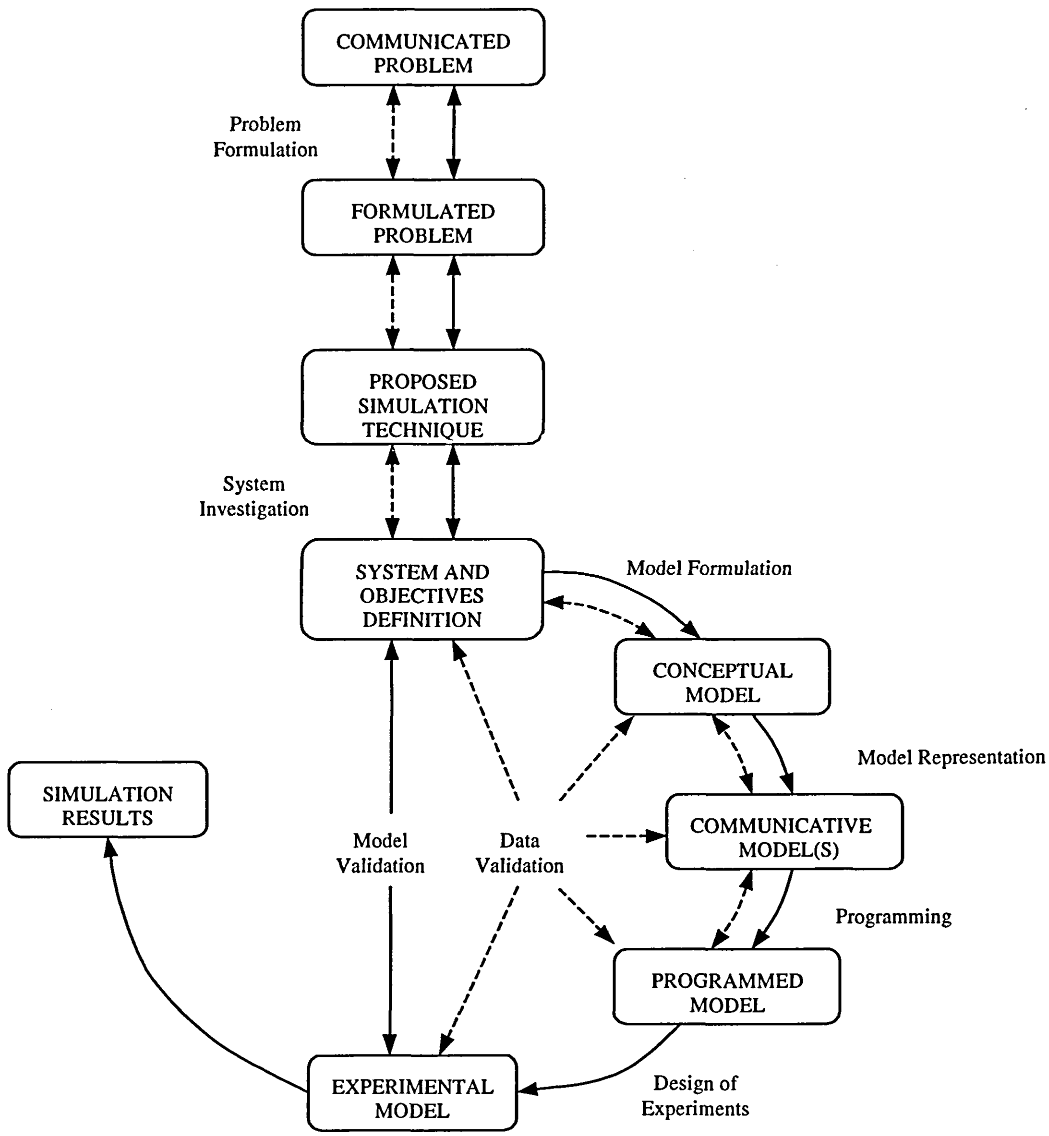

Figure 1-2 Balci and Nance's procedure (based on Balci and Nance 1990)

The analyse of the procedures, which are described in the literature shows that simulation project life-cycle generally can be divided into four main stages:

- Project/Objective definition,
- Model building and testing
- Experimentation
- Project completion and documentation.

The literature review also stressed the requirements for carrying the verification and validation procedures at every stage of the project. The identified main stages of simulation project are used in experiment described in Chapter 7.

1.4 Simulation Team and Team Working

Because the concept of the simulation team is applied in farther research following subchapter recapitulates the characteristics of the teams, team working and simulation team.

Successful simulation projects require strong teams and full participation from every individual involved in the project. Every team member must buy into the process by understanding where the project is going and what is required of them for it to be a success.

Benefits of collaborative and collective effort to overcome problems
Teams produce a greater quantity of ideas and information than individuals acting alone
Teams improve understanding and acceptance among individuals involved in the process
Teams create higher motivation and performance levels than individuals acting alone
Teams offset personal biases and blind spots that hinder the decision process
Teams sponsor more innovative and risk taking decision-making.

Table 1-2 Benefits of teamwork (Mayer 1967)

1.4.1 Characteristics of successful team

Hirschorn (1991) identified the characteristics and property of efficient functioning teams:

- Clear, elevating goals
- A results driven structure
- Competent members

- Unified commitment
- A collaborative climate
- Standards of excellence
- External support and recognition
- Principal leadership

Larson and LaFasto (1989) and Bennis and Nanus (1986) noticed that the more an individual or a group of people have a clear understanding of the nature of the problem that confronts them, its worth and importance, the more effective they will be in looking for a solution. But when goals become unfocused or politicised, the team lost it's sense of urgency or priority about its objective, the team's effort become divided, too many other competitive goals, or individual goals take priority, the whole teamwork become inefficient and painful for members of the team.

Briefly, the clarity of the goals implies there is a specific performance objective, phrased in such concrete language that it is possible to tell, unequivocally, whether or not that performance objective has been attained (Leigh and Maynard 1995).

The goal can be personally challenging to the individual and/or collective effort and also can be elevating because it challenges-stretching the limits of physical and mental abilities of team members (Chang 1995). It offers an opportunity to excel. However the goal can be evaluated in the sense that the performance objective itself makes a difference – creating a sense of urgency and importance.

1.4.2 Result-driven structure

The properly organised team should have a specified structure with responsibilities and communication channels for the co-ordination of its activities. The importance of a defined structure becomes especially visible and painful during any disaster or crisis. However, the effective structure is more than merely having the basic components in place. The significance of a structure lies in identifying the appropriate structure for the achievement of a particular performance objective. A specific configuration that does not confuse effort with results and that makes sense to the team members involved.

Teams should be designed around the results to be achieved, rather than around any pre-existing circumstances. For a functional and useful structure, it must be established in such a way that combined and individual efforts lead towards achieving objectives. There are a number of alternative team structures, which Larson and LaFaste (1989) divided into three main kinds (Table 1-3): problem resolution, creative and tactical.

Broad Objective	Dominate feature	Process emphasis
Problem resolution	Trust	Focus on issue
Creative	Autonomy	Explore possibilities and alternatives
Tactical	Clarity	Directive Highly focused task Role clarity Well-defined operational standards Accuracy

Table 1-3 Basic structures of team (Based on Larson and LaFaste1989)

1.5 Simulation Team structure

The structure of a simulation team is described in this subchapter, as the reorganization of a simulation team into a virtual simulation team is the subject of that research.

Simulation is usually used to solve problems that appear in systems. To look for optimal parameters to control systems a simulation team should be organised as a problem reduction team. However a creative simulation team can be used as a support tool during the designing of a new system.

1.5.1 Problem Resolution Teams

A team is organised to resolve problems on an ongoing basis. When this is the broad purpose of the collective team effort, the most important and necessary feature is trust. Each member of the team must expect, and believe, that interactions among members will be truthful and embody a high level of integrity. Also the members must believe that the team will be fairly consistent and mature in its approach to dealing with problems.

This kind of team requires the balance between closeness to the problem and the availability of the necessary resources and depends on the presence of a centralised body of expertise. It is a structural configuration that allows for the quickest response to a problem, the most thorough investigative effort, the creation of a database decision-making process, and managing resources and expertise. The team members should be people who have firsthand knowledge of, and experience with, the problem, people who command technical and supporting resources (Larson and LaFaste1989).

1.5.2 Creative Teams

When the broad objective of the team emphasises creativity, then a necessary feature of the team's structure is autonomy. The process focuses the creative team on exploring possibilities and alternatives. However for creative team to function, it is necessary to have autonomy from systems and procedures, as well as to create an atmosphere in which ideas can be developed and promoted (Larson and LaFaste 1989).

1.5.3 Simulation teams

The simulation team project should consist of people who are specialists in their discipline, representing a high level of competence and commitment. However the personal predisposition of people to work as a member of the group also needs to be considered (Nastings et al. 1986). Figure 2.4 shows seven roles that typically exist in any simulation study.

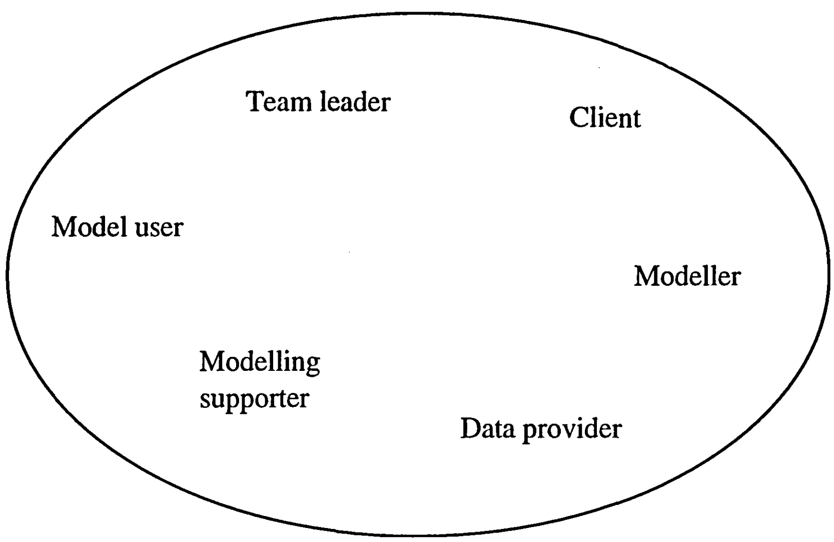

Figure 1-3 Team participants in simulation project life cycle (Robinson 1994)

The team leader. Team leadership is vital if the direction of the project is to be set, the tasks identified and the time scale kept. The team leader does not necessarily have to be involved in the modelling process. In fact it may be an advantage if team leader is not involved in model building, which enabling him to concentrate his effort on the leadership of the team.

The Client is project sponsor and the recipient of the results. Clients have identified a problem and seek a solution through simulation. They could be the board of directors, a manager, an operator or an external customer. It also may happen that the project has more than one client with each having different opinions concerning the problems and their potential solution.

The Modeller builds and tests the simulation model. Modellers need to have gained expertise in the software package. They can be a full time simulation expert or work temporarily on simulation for the duration of the project, alternatively a consultant could be employed to perform the modelling role.

The Model User is the person who will use the simulation model in the future, after completing the project. The model may be passed to a user for experimentation. The user is close to the problem and so well placed to seek a solution but users do not need to have the necessary skills to build their own models. However, they need to be competent in performing experiments and analysing results.

The Data Provider is an expert in the system being modelled and either has direct access to the data or knows where it can be found. Because simulation requires a great deal of data (including layout, timings, flows, control logic and constraints), in more complex studies more than one data provider may be required.

The Modelling Support is required to join the team and support the simulation process in a more complex problem. That person supports the team in such aspects as model building, model testing and experimentation. Modelling support can be obtained from the software vendor, consultants or in house expertise.

1.6 The Internet impact on simulation

That subchapter recapitulates the data obtained during the literature review on the subject of implications made by Internet technologies on the simulation technology and methodology.

Fisher (1997) described the Internet as a giant network of computers located all over the world that communicate with each other. As a fact the Internet today is the premier network of networks, characterised by an incredible diversity of users and applications combined with an even more dazzling rate of growth. The emergence of World Wide Web (WWW), with its intuitive interface and its system for organising and locating resources through hypertext protocol (HTTP), has changed the look and feel of the Internet (Cronin

1996). It becomes not only a useful scientific or business tool but also the place of fun and joy with high-quality graphics, multimedia, and personal Web-sites.

The possibility, connectivity and resources offered by the Internet represent an enormous opportunity for business and its innovation. Cronin (1994) pointed out that even the smallest company could use the network to exchange data with customers or suppliers on the other side of the world. The Internet technologies, with its communication tools like e-mail, newsgroup, or chat room, have revolutionised the collaboration and communication between companies, organisations, and people. It also offers an unprecedented and easily obtained access to the outside world information sources. This information and its creative applications provide the crucial new opportunities for organisations to move ahead of their competition. In order to make better decisions, managers and employees require updated information about situation and trends and the marketplace. To confirm the foregoing words I quote Peter Drucker (1993), a management guru, who said that the most important source of information comes not from internal data but from the outside world.

The following subchapter describes the impact of the Internet technologies on simulation methodology.

1.6.1 Web-based simulation

The emergence of the World Wide Web (WWW) and its related technologies as HTML, HTTP, CGI, etc, has produced an environment within which many disciplines are re-evaluating their inherent approaches, techniques and philosophies. According to Page and Opper (2000) the disciplines concerned with computer simulation are no exception and the concept of "web-based simulation" becomes the subject of much interest to both the simulation researcher and simulation practitioners. Since 1996 the web-base simulation has a special panel session at the Winter Simulation Conference, which is the largest annual gathering of simulation professionals in the world. Moreover in January 1998 the first conference dedicated to the topic of web-based simulation (WEBSIM 98) was held as part of the annual Society of Computer Simulation (Fishwick et al 1998).

Today the Web is a common framework for working, collaborating and doing business, and as result simulation is used more frequently as a support tool in a wide spectrum of applications that operate directly on the WWW. Web issues are increasingly utilised to exploit simulation benefits, to connect information resources, to search for solutions and to collaborate and co-ordinate activities in teamworking. According to Bruzzone (2001) there is no doubt that in net-based electronic business, simulation will be a strategic competitive advantage, and skills, research and tools on this subject will become very important.

Kuljis and Paul (2000) describe the Web as a truly democratic and non-exclusive medium that can become an operating system and a distribution channel for applications, which is easy to use and navigate through. According to Kalakota and Whinston (1997) it creates a new publishing medium, a new distribution model environment, and enables new intra-business applications.

Banks and Chair (2000) presented the advantages of moving simulation into virtual reality where consultants and clients would both benefit from web-based simulation capability. Models could be reviewed with clients via Internet during model development. A consultant could make changes to a model via Internet without travelling to the client's side. Data files could reside in one central place for access by the model from any location in the client network, Models could be shown to a large audience via the Internet during a single session. Web-enabled simulation would also reduce the cost of software maintenance while at the same time increasing the use of the simulation software. Furthermore Jain (1999) pointed at possibility of the integration of simulation systems, manufacturing planning and scheduling systems into decision support systems across the Internet. Virtual teamworking philosophy would allow moving collaboration and communication during the simulation project life cycle on an electronic platform.

Fishwick (1996) identified several potential impacts of web technologies on simulation, with attention given to three key areas:

1. Education and training (ex. Tam et al. 1999, Bender et al. 2000, Ferrero and Piuri 1999).
2. Publication (ex. Mohtar et al. 2000)
3. Simulation programs (Java-based solutions)

However, Page (1998) extended Fishwick categories, and distinguishes five primary areas of web-based simulation:

1. *Simulation as hypermedia.* Text, images, audio, video simulation – the nature of the WWW design enables the production, storage and retrieval of "documents" containing any or all of these (and other kinds of) elements. The availability of simulation as the desktop, browser-based commodity has the potential to significantly alter current teaching and training methodologies, both for simulation as a technique, and for disciplines that apply simulation, like engineering, physics, and biology. Paradigms that

focus on distance learning and interactive, simulation-based education and training are emerging.

2. *Simulation research methodology.* The ability to rapidly disseminate models, results and publications on the web permits new approaches to the conduct of simulation research, and scientific research in general. The practical, economic and legal issues associated with the electronic publication of documents, for example, are numerous (Samuelson 1996). The electronic publication of simulation models raises additional considerations.
3. *Web-based access to simulation programs.* Most commonly associated with the term web-based simulation, this area includes both the remote execution of existing (so-called "legacy") simulations from a web browser through HTML forms and CGI (Common Gateway Interface) scripts, and the development of mobile-code simulations (e.g. applets) that run on the client side (Yang 1999).
4. Distributed modelling and simulation. This area includes activities that deal with the use of the WWW and web-oriented technologies (e.g. COBRA, Java RMI) as infrastructure to support distributed simulation execution (Klein et al. 1998, Page et al. 1997, Sajoughian and Ziegler 1998). Internet gaming is included here, as is research in tools, environments and frameworks that support the distributed (collaborative) design and development of simulation models (Cubert and Fishwick 1997)
5. Simulation on the WWW. Modelling and analysis of the WWW for performance characterisation and optimisation.

However Taylor (2000) focused the potential impact of the Internet-based collaboration and communication technologies on a simulation project life-cycle. He recognised that Computer Supported Cooperative Work (CSCW) and Groupware technologies could redesign the interactions between parties involved in a simulation project. He also pointed that frequent meetings of simulation team can could lead to extended project times and high final cost and investigated the usefulness of the NetMeeting software in the process of the collaborative model development (Taylor 2001).

As the results of literature review the idea of the first research question was generated, which addressed simulation practitioners' expectations and opinions associated with the Internet technologies.

Research questions:
How can the Internet based solutions be applied in the life-cycle of simulation project in order to improve efficiency of the simulation team?

1.7 Technology in Virtual Team

As the study progress the author had to choose the appropriate technology to support activities in a virtual simulation team and available technology is described in the following subchapter.

The network based applications created new rich methods for communication and collaboration process between parties involve in simulation project. However, the choice of right technology has a great impact on a success of virtual teamworking. The technology needs to allow establishing effective communication and collaboration over space and time. Introducing the technology needed for virtual teamwork, the team leader has to considering number of factors, such as:

- resources
- project's budget
- information richness and social presence
- people preference and experience
- project's requirements and their implication for support systems

There are two primary factors that can help virtual teams to evaluate apprehensive technology: (1) social presence and (2) information richness.

The ideal technology depends on the task and it is different from one situation to another.

Duarte and Snyder (2001) argued that the choice of ideal technology depends on the type of the task and it is different from one situation to another. They produce a task/communication matrix (Table 1-4), which provides guidance in selecting appropriate communication technology to suit the type of task.

	Type of task			
Communication models	Generating Ideas, Plans and Data Collecting	Problems with Answers	Problems without Answers	Negotiating Technical or Interpersonal Conflicts
Only Audio	Marginal fit	Good fit	Good fit	Poor Fit
Only Video	Poor Fit	Good fit	Good fit	Marginal fit
Only Text - Chat	Marginal Fit	Good fit	Good fit	Poor Fit
Only Data (e.g. e-mail, web-pages)	Good fit	Marginal fit	Poor Fit	Poor Fit

Table 1-4 Task/communication matrix (based on Duarte and Snyder 2001)

According to Cutkowsky et al. (1996) the virtual team's dependence on integrated communication technology requires these media links to be reliable, numerous, rapid, must support data and information transfer, generate shared interpretations of data and information, and the resolution of conflicts. Suchan and Hayzak (2001) argued that these communication links must support not only information transfer but also patterns of social relations in the form of mentoring, coaching, and conflict resolution, which develop team trust, member satisfaction, and commitment. The lack of the nonverbal communication may limit the team integration, members' feedback, and leads to complex and reiterative exchange of data (Strauss 1996) that can become the potential source of conflict in virtual teams (Montoya et al. 2001).

However, Stangor (2000) focused a paradox that the lack of face-to-face interaction or rich nonverbal communication may become the advantage of a virtual team. Without social influence the team members can be judged by their performance rather than on stereotypical cues.

1.7.1 Social Presence

Social presence is the degree to which the technology facilitates a *personal connection* with others (Duarte and Snyder 2001).

Interactions with high social presence are described as more lively, social, warm and intimate than those with little social presence. For example the face-to-face meeting has the highest level of social presence compared to text message, e-mail or business letter.

However, the high level of social presence is not necessary always better. Sometimes the low level of social presence may reduce interpersonal distractions, such as appearance, mannerism and being reminded of previous negative interactions with the person or group. The technologies with less social presence can be used for regular exchange of information between team members or other routine situations, while technologies with higher social presence may be suitable for non-routine situations containing high interpersonal or emotional components or ambiguity and uncertainty.

1.7.2 Information Richness

Technologies with high information richness are those that help to accurately transfer clues to the meaning of the communication and thereby reducing confusion and misunderstanding (VTASC 1999). Social presence can be defined by the amount and variety of information flowing through a specific communication media. Video conferencing is the technology that provides the highest level of information richness as it presents a large amount of information, such as spoken words, facial expressions, body language and environment information about each attendee's surroundings. The other forms of communication such as e-mail or audio conference produce relatively lower level of information richness.

1.7.3 Other Factors

Apart from these two factors, other factors that influence the team's selection of technology are as follows:

- *Permanence* – the degree to which the technology is capable of creating a historical record of the team interactions or decisions.
- *Experience and Familiarity with Virtual Operations* – experienced virtual team members often find high social presence or information-rich environment distracting and call them a waste of time.
- *Time Constraints* – there is often not sufficient time to select and procure the optimal technology and to train people to use it.
- *Access to Technological Training and Support* – some technologies may not be available to all team members, or there may be issues regarding the compatibility of

systems or the availability of hardware and software in certain parts of the organizations or in partner organizations.

- *Symbolic Meaning* – refers to the context (meaning) over and above the message that is implied by the technology, such as receiving a hand-written thank-you letter rather than a typed one.
- *Cost of implementation* - refers to budget of the project and total cost of software, hardware and training session

1.7.4 Available Technologies

The term groupware, which refers to electronic systems that integrate software and hardware, is used to describe the entire category of electronic tools available for the virtual team.

The following section describes the most popular groupware application outlined by Coleman (1997). The groupware can be divided into two general categories:

- synchronous - those that enable team members to interact at the same time
- asynchronous - those that facilitate delayed interaction

Synchronous groupware includes:

- Desktop and real-time data conferencing
- Electronic meeting system (EMS)
- Video conferencing
- Audio conferencing
- Messaging systems

Asynchronous groupware includes:

- E-mail
- Group calendars and Schedules
- Bulletin boards and Web pages
- Non-real-time database sharing and conferencing
- Workflow application

Table 1-5 presents effectiveness of communication methods in particular situations.

	Purpose of meeting			
Type of technology	Generating Ideas, Plans and Data Collecting	Problems with Answers	Problems without Answers	Negotiating Technical or Interpersonal Conflicts
Desktop and real-time conferencing (electronic chat)	useful	useful	least useful	least useful
Multipoint, multimedia, real-time data conferencing	useful	very useful	very useful	useful
Electronic Meeting System	very useful	useful	useful	useful
Electronic Display with Voice	useful	useful	useful	least useful
Video Conferencing	least useful	useful	useful	useful
E-mail	useful	useful	least useful	least useful
Bulletin Boards and Web Pages	useful	useful	least useful	least useful
Non-Real-Time Data Conferencing	useful	useful	least useful	least useful

Table 1-5 The comparison of the communication tools for virtual teamworking (source: Duarte and Snyder 2001)

1.7.4.1 Desktop and real-time data conferencing

This groupware connects team members in synchronous interaction from their computer workstations. Such systems allow people to store common documents, and access to tools, including electronic chat and whiteboards.

Electronic chat allows team members to have typed conversations with other team members, where the questions, response and comments of all participants are visible in a chat window on each participant's desktop monitor (Duarte and Snyder 2001).

A whiteboard is the tool that allows team players to view a shared document, to diagram ideas on their computers and see the comments of other participants. Whiteboards are most effective with added communication links, such as audio, video, or the chat windows.

The most advanced application of desktop and real-time conferencing includes full video and audio capabilities, which allows team members to see and hear each other. That multimedia solution is ideal for team tasks that require a high amount of information richness and social presence

1.7.4.2 Electronic meeting system (EMS)

The EMS brings meeting participants together in a structured and organized way around define topics, problem statements, and objectives. According to Coleman (1997) the collaboration is steered by the team's facilitator, who should not restrict innovation or creativity, but guide the group to meet some specified objectives.

EMS becomes more compatible with other typical applications like word-processing, spreadsheet, or project management software. In spite of typical communication links such as e-mail, audio-video, chat, EMS provides additional tools to address typical tasks in teamworking such as brainstorming, voting, outlining or annotating.

EMS is the perfect software for teams that collaborate tightly and require a lot of meetings in which ideas can be generated, issues categorized and prioritised. Duarte and Snyder (2001) described the EMS as a technology that provides high level of social presence and information richness. However, those systems require a significant economic investment in software and organization culture, and there is a need for a skilled system's facilitator.

1.7.4.3 Video conferencing

There are two types of video application:

- desktop video - the software and hardware are installed on team members machines,
- specialized video facilities - the organization has specialized video rooms with video equipment and high bandwidth networks to transmit full-motion video.

Video conferencing can provide high information richness and social presence. However the quality of the video picture strongly depends on the bandwidth, which is determined by the type of network, capacity of cables, speed of the computer modem, congestion in the network, etc.

1.7.4.4 Audio conferencing

The telephones and telephone based conferencing systems are the most common and popular tools in teamworking. According to Pauleen and Yoong (2001), people are very familiar with the phone and its use is second nature because it has been around so long and it does not carry the "baggage of new technology". Phone calls are so obvious a communication with high level of social presence, and information richness. It is widely used to build relationship with clients and consultants, and generally applied to initiate business.

1.7.4.5 Messaging systems

Those systems allow sending messages to other computers nearly in real time. Some of them have additional functions that allow its users:

- to find when virtual team members anywhere in the world are connected to the Internet,
- to open a chat box to hold fully synchronous typed conversation,
- to transfer data and files between computers.

1.7.4.6 E-mail

E-mail is the most pervasive and successful computer groupware for distance collaboration. It is the electronic version of the postal service, generally accessible, cost effective, easy to learn, gives people time to think and consider their responses. Its advantages include fast, concise messaging with the added benefits of being able to send the same letter to a number of different people and distribute documents or/and files as attachments.

Most e-mail systems provide the possibility of tracking the source and journey of the original message. Moreover the systems can notify the receiver that a message was delivered and when opened, they even can filter and prioritise incoming messages

Duarte and Snyder (2001) described the e-mail as an excellent way to communicate and share information. However they point to the low information richness and lack social presence as the weakness of it.

1.7.4.7 Group calendars and Schedules

The need of time and work coordination makes calendaring and scheduling application very important for a virtual team. Following Coleman (1997) specification calendaring involves the manipulation of information on an individual's calendar while scheduling involves the coordination between individual calendars. Those tools are meant to be used for team coordination effort and they have no social presence or information richness. They are not adequate to resolve technical or interpersonal issues in the virtual team.

1.7.4.8 Bulletin boards and Web pages

Electronic bulletin boards and Web pages provide shared work spaces for the posting of messages and ideas, the displaying and editing of documents, and for non-real-time discussions (Duarte and Snyder 2001). They are particular useful to present, share and gather large amounts of data. These methods allow people to build on, deliberate and comment on the ideas of others. A specialized database can be applied as a part of the application in team collaboration and project documentation.

These technologies have a low level of social presence although they are relatively inexpensive, easy to learn and maintain.

1.7.4.9 Non-real-time database sharing and conferencing

Shared database systems were one of the first groupware applications and they can be used to perform a number of information management functions, such as providing access to reference materials, stored data and documents, searching for relative information, updating documents, etc. Shared databases usually accept a wide range of data, including multimedia information. Information can be frequently distributed through involved participants. Individual team members have access to the database and freedom to search the database, or even in some cases the possibility to tailor the system for their own use.

Non-real-time databases contribute to permanence but have little social presence and information richness (Duarte and Snyder 2001)

1.7.4.10 Workflow application

Workflow applications are applied by organizations to repetitive business processes that involve similar sequential steps. These are rather very specialized solutions to optimise and automate workflow.

On the IT market there are available technologies to support virtual collaboration and teamworking. However, the different activities/tasks during simulation project life-cycle required the appropriate tools. The suitable analyse was made during a methodology and an application process development, which is described in Chapter 4 and 5.

2 Research methodology and preliminary work

The previous chapter presents the literature review on the simulation methodology, teamworking and the impact of www technologies on simulation. In the next step of the research the author recognized a need to identify views and requirements of simulation practitioners on the subject.

The initial stage of this study was devoted to establishing an effective research methodology, which was motivated by the need to elicit knowledge, views, and predictions of people involved in simulation concerning the research questions.

The research methodology was composed of a questionnaire survey and a cross-sectional literature review that refers to the research subject. The rationale behind the selection of these techniques was determined by the nature of the first research questions being of an exploratory nature. That allowed the identifying of the next research operation and establishing the following research questions. Two multiple data collection techniques were deploying in order to maximise and strengthens data collected (Eisenhard 1989, Yin 1994, Denscombe 1998).

2.1 The research process

Gilbert (2001) described the research process as the two correlated methods (Figure 2-1):

1. Deduction – technique for the application of theory to process,
2. Induction – technique for generating theory from process analysing.

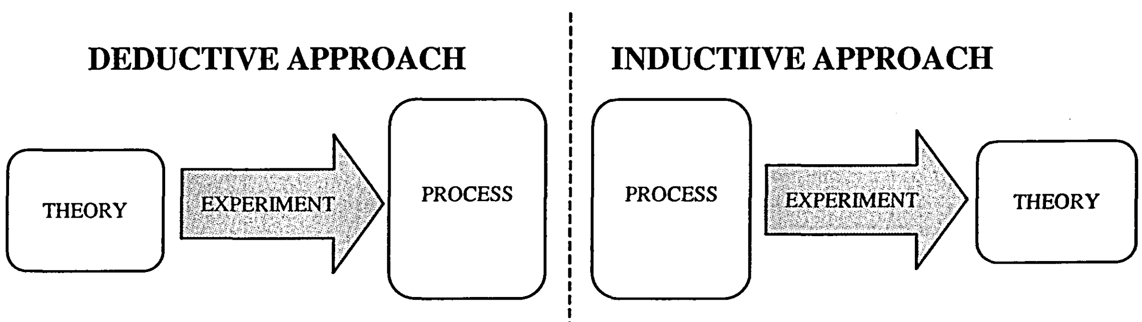

Figure 2-1 The research process

Gill and Johnson (1991) depicted the deductive research method as being the development of a conceptual and theoretical framework prior to testing through empirical observation, and the output is the generation of new experiences and observations. In contrast to deduction, the outcome of induction is theory, which is being developed from observation of the empirical world. However, Baker (1988) pointed out that a scientific model is incomplete without both procedures and that in practise it is difficult to separate them. He also says that researchers do not have to complete every stage of the research process in a single project, and it is possible to move from observation to theory generation (inductive research) or to start with theory followed by testing (deductive research). Eisenhardt (1989) who stated that it is impossible to achieve an ideal of a clean theoretical state supported this opinion.

Table 2-1 presenting the detailed summary of deductive and inductive research features made by Gill and Johnson (1991).

Deductive methods	Inductive methods
Explanation via analysis of casual relationship and explanation by covering-laws	Explanation of subjective meaning systems and explanation by understanding
Generation and use of quantitative data	Generation and use of qualitative data
Use of various controls, physical or statistical, so as to allow the testing of hypnotises	Commitment to research in everyday settings. To allow access to, and minimise reactivity among the subjects of the research
Highly structured research methodology to ensure replicability of above characteristics	Minimum structure as to ensure above characteristics

Laboratory experiments	Quasi experiments	Surveys	Action Research	Case Studies	Ethnography

Table 2-1. Characteristics of deductive and inductive research (Gill & Johnson 1991)

The inductive approach is deployed to obtain data to answer the first research question (Chapter 2.2). However, the deductive method is applied to develop a methodology for establishing a virtual simulation team (Chapter 4).

2.2 Summary of the deployed research methods

2.2.1 Questionnaire Survey

Denscombe (1998) portrayed the survey approach as a research strategy, which principles allow effective mapping of the social world as well as the physical world. Some of the surveys' crucial characteristics are:

- Wide and inclusive coverage - it should have a wide coverage and panoramic point of view.
- At specific point of time – it usually refers to the present state of affairs and involves an attempt to provide a snapshot of how things are at a specific time.
- Empirical research – it involves looking for necessary information at source.

Surveys come in a wide variety of forms as: postal or email questionnaires, face to face or telephone interviews, etc.; and are used by researchers who can have different research aims and discipline backgrounds. Gill and Johnson (1991) focused on the fact that the nature of a survey depends highly on research objectives and the personal disposition of the researcher. They also distinguish two kinds of surveys - analytic and descriptive. The main aims of descriptive surveys are to generate a body of information from which insight and theory can be generated. In contrast, the analytic surveys' main aims are to test out the validity of causal relationship.

Bryman (1988) presented a survey as a capable method of generating a number of quantitative and qualitative data by examining large numbers of people who are known to be representative of a wider population in order to test theories and hypothesis.

Qualitative research employs a variety of strategies and methods to collect and analyse a variety of empirical materials (Denzin & Lincoln 1994), which produce descriptive data. According to Bogdan and Taylor (1975) qualitative methods enable us to explore concepts whose essence is lost in other research approaches, such as people experience in their every day life. The task of the qualitative methodologist is to capture what people say and do as a product how they interpret and understand the events from the viewpoints of the participants. Burns (2000) in his book emphasises that qualitative research places stress on the validity of multiple meaning structures and holistic analysis, as opposed to the criteria of reliability and statistical compartmentalisation of quantitative research.

Quantitative research is associated with a number of different approaches to data collection and according to Bryman (1988) is based on a special language, which appears to exhibit some similarity to the scientist such as variables, measurements, controls, etc.

Although qualitative research has become a prominent strategy in some areas of science, it is by no means as pervasive as quantitative research, and according to Bryman (1988) and McNiff et al. (1998) the fusion of those two techniques can bring only better and more comprehensive results.

2.2.2 Questionnaire development and deployment

The questionnaire was the first method to be developed and deployed in the study. The aim of the survey was to collect data both qualitative and quantitative to answer the first research question. Collected information from this survey and literature review generated the route and next research step on which the study was conducted.

The objectives of the questionnaire were as follows:

- To gather general information on practising modellers, for example their professions, and actual employment – it provides the basis for interpreting the data collected.
- To investigate their opinions on the influence of the Internet technologies on simulation projects – it provides data to answer the first research questions.
- To discover their opinions on the different Web-based solutions and future challenges – to indicate the path of the research.

A descriptive survey was done rather than an analytic one as there was no testing of the hypothesis but asking for personal opinions and experience.

The questionnaire survey was conducted over the Internet in the winter of 2000. Practitioners who participated in newsgroup comp.simulation received the survey with a request to participate. The newsgroup comp.simulation is the most popular group that gathers the people involved in all kind of computer simulation.

The questionnaire survey provided rich data concerning the current state of Web-based simulation and allowed the obtaining of opinions and expectations of people involved in simulation projects. The analysis of the survey results informed the direction of this research.

2.2.3 Questionnaire results

A total of 27 questionnaires were completed and returned. Some participants did not provide identification data, however their qualitative and quantitative data were included in final results.

Table 3-2, Table 2-3 and Table 2-4 present the summary of data from questions addressing the background and profession, people's previous experience in Web-based technologies, and their opinions.

Number of respondents	Background/Profession
6	Simulation Practitioner
4	Simulation Consultant
8	Teaching
9	Simulation Research
3	Software Development
2	Management

Table 2-2 The background of the respondents

Number of respondents	Previous contact with Web-based technologies to support simulation project
15	No
12	Yes

Table 2-3 Respondents experience in using Web-based technologies during simulation process life cycle

The result shows that about 44% of the survey participants have applied Web-based technologies during simulation project life cycle. Furthermore, most of the participants, about 70%, who declared that they haven't used the Internet technologies in a simulation project before, admit their interest in those techniques and tools. They express positive opinions and see advantages of a wide spread of networking technologies.

However, there are also answers that represent negative reflections such as those presented by:

Jim Henriksen (Wolverine Software, senior software development)

> *Vastly overrated. Academic interest springs from the appeal of the technology. In practise, web-based simulation is rarely used outside the government and academia.*

Or Karl Johan Grinnemo (Ericsson Infotech AB, system engineering)

> *Except from using it to distribute the results, I don't see that many advantages using the Web as compared to a traditional environment.*

Collect and confirm input data	Collaborate model development	Distribute simulation models	Model documentation	Collect and distribute output data	**The scale of answer:** 1 - strongly disagree to 5 - strongly agree
3.33	2.93	3.80	3.73	3.53	

Table 2-4 Respondents' opinions indicating the importance of the Web-based solution in a simulation project.

The participants were asked to voice their opinions about the impact of the Internet technologies on basic processes during simulation project life cycle (see Table 2-4). The result shows that the applications with the most potential are seen in using Web to:

- Collect and confirm simulation-input data,
- Distribute simulation models,
- Create and present model documentation,
- Collect and distribute simulation-output data.

The poll's contributors pointed to the advantages of the WWW environment such as: independence platform, popular and easy to use, which allows sharing resources over the Internet connection. Some of survey participants admit using the Internet technologies to share documents, collect and distribute data, and many of them see WWW as a future platform for carrying large simulation projects. Ovsei Volberg (Unigraphics Solution) gives especially interesting opinions:

> *Web is an important tool to manage projects and communicate ideas, models, documentation files and results between multiple R&D locations. I use the e-Vis for collaborative project development including sharing project files, documents and movie files...*

Compiling that with Ken Buxton's (Rockwell Software) reflection:

> *Consultant and clients would both benefit from Web-based simulation capability. Models could be reviewed with clients via the Internet during model development. ... Data files could reside in one central place for access by the model from any location in the client network. Models could be shown to a large audience via the Internet during a single session.*

which was presented by Banks and Chair (2000) in the paper "Simulation in the Future". The same paper also quotes the words of Onur Ülgen (Production Modeling Corp.):

Web-enabled simulation can expand the use of simulation by providing global support for the users, interactive and collaborative model building, validation and analysis....

Web-enabled simulation will also reduce the cost of the software maintenance while increasing the use of the simulation software.

The results of the questionnaire and data from literature review allow establishing the state of the research. In summary, it was found that the processes of carrying on the simulation project in the virtual environment of the Internet are not well documented. Though general guidelines and methodologies are available to establish an efficient virtual team, they do not take into consideration the specifications of the simulation project. The observed lack of documentation drove the formulation of the second and third research questions:

Research questions:

How do we establish virtual simulation teams?

How can we apply the virtual teamworking concept into the simulation project life cycle?

What technology should be used to support the virtual simulation team?

What are the implications of virtual teamworking on a simulation project?

3 Virtual Team Technology

Having some evidence of simulation practitioners' interest in applying the virtual team philosophy into simulation project life-cycle (Chapter 2.2) that chapter introduces the concept of virtual teamworking. The definition and the main characteristics of virtual team are presented, as the concept of virtual team is a keystone of that project.

The formation of team philosophy becomes a more and more popular concept in corporations (Grimshaw and Kwok 1998), which reshape their structure to maximise their strengths to address problems (Quinn 1992). In today global market however, it is converted into a virtual team philosophy, as it is difficult and costly in the global market to assemble all team member in one location (Stough et al. 2001).

3.1 Definition and characteristics of virtual team

Lipnack and Stamps (1997) defined a virtual team as "a group of people who interact through an interdependent task guided by common purpose" and "work across space, time and organisational boundaries with links strengthened by webs of communication technologies". While Henry and Hartzler (1998) described it as "groups of people who work closely together even although they are geographically separated by miles or even continents" and as "intact workgroups or cross functional groups brought together to tackle a project for a finite period of time through a combination of technologies". Recapitulating, virtual teams are geographically dispersed, driven by common purpose, enabled by communication technologies, and involved in cross-boundary collaboration. Bal and Teo (2000) concluded that team becomes virtual if it meets the four common criteria, and usually has other characteristics, that are summarised in Table 3-1.

Characteristics of virtual team	Description
Four common criteria	Geographically dispersed Driven by common purpose Enabled by communication technologies Involved in cross-boundary collaboration
Other characteristics	It is not permanent team Members solve problems and make decisions jointly and are mutually accountable for team results Small team size Inconsistent membership Team members are knowledge workers

Table 3-1 Characteristics of virtual teams (based on Bal and Teo 2000)

3.2 Types of virtual teams

There are many different configurations of virtual teams, and team leaders and members need to have a solid understanding of which type of virtual team they work in, and the special challenges each type presents. Table 3-2 summarises seven types of virtual teams identified by Mittleman and Briggs (1998) and described by Duarte and Snyder (2001).

Type of teams	Description
Networked teams	Consist of individuals who collaborate to achieve a common purpose. Such teams frequently cross time, distance, and organisational boundaries. Membership is diffuse and fluid, with members rotating on and off the team as their expertise is needed
Parallel teams	Carry out special assignments, tasks, or functions that a regular organisation does not want or is equipped to perform. Such teams frequently cross time, distance, and organisational boundaries. It has distinct membership that identifies it from the rest of the organisation. The members typically work together on a short –term basis to make recommendations for improvement in organisational process or to address specific issue
Project or product-development teams	Team members conduct projects for the customer for a defined period of time. Such teams also cross time, distance, and organisational boundaries. Their tasks are usually non-routine, and results are specific and measurable. Exist longer than parallel teams and have a charter to make decisions not recommendations. Membership is inconsistent but is more clearly delineated from the rest of the organisation
Work or production teams	Perform regular and ongoing work. Such teams usually exist in one function. Membership is clearly defined and can be distinguished from other parts of the organisation. The teams are now beginning to operate virtually and across and distance boundaries
Service teams	Service teams are now to be distributed across distance and time. The teams work on a rotating basis so that one team is always operational, providing a 24-hour service. Each team works during its member's daylight hours and transitional work and problems to the next designated time zone at the end of the day
Management teams	Distance and time can separate management teams. These teams often cross national boundaries but they almost never cross organisational boundaries
Action teams	Such teams offer immediate responses, often in emergency situations. They cross-distance and organisational boundaries.

Table 3-2 Types of virtual teams (based on Duarte and Snyder 2001)

3.3 Critical Success Factors for Virtual Teams

The virtual teams increase speed, agility and leverage expertise with vertical integration between organisations to make resources more readily available. They also lessen the disruption of people's lives because the people do not have to travel to meet. Team members can broaden their careers and perspectives by working across organisations and cultures and on a variety of projects and tasks.

Although the effective use of electronic communication and collaboration technologies is fundamental to the success of a virtual team, it entails much more than technology and computers. Duarte and Snyder (2001) described seven critical factors for virtual teams, of which technology is only one. Others are human resources policies, training and development for team leaders and team members, standard organisational and team processes, organisational culture, leadership, and leader and member competencies. These are presented in Table 3-3.

Critical Factors	Description
Human resources policies	Systems must be integrated and aligned to recognise, support and reward people who work in and lead virtual teams
Training and on-the-job education	Formal training in using technology is vital for success. Provide training and support for your team in working collaborative across organisational, cultural, and functional boundaries
Standard organisational and team processes	The use of standard processes reduces the time needed for team start-up and may eliminate the need for unnecessary reinvention of operating practises each time a team is chartered. Practise need to be flexible and promote adaptation to a particular virtual team's situation.
Electronic communication and collaborative technology	The members of the team have to have access to selected technology that meets their needs.
Organisational culture	Includes norms regarding the free flow of information, shared leadership, and cross boundary collaboration.
Leadership support of virtual team	The organisation's leadership must establish a culture that values teamwork, communication, learning, and capitalises on diversity. Also managers and team leaders at all levels must be open to change and must support virtual teamwork.
Team leader and team member competencies	Team leaders have to establish trust in an environment with little or no face-to-face contact or feedback, and all team members have to develop their own competencies

Table 3-3 Critical success factors (based on Duarte and Snyder 2001)

4 Proposed methodology

That chapter presented the developed methodology for transferring the simulation team into virtual one.

Virtual teamworking in the simulation project life cycle is a relative new research area, which has not been given sufficient attention. Although there are some literature guidelines for virtual teamworking most of the authors have focused their research on executives' work. They are focused on the business process and do not take into consideration the specific requirements of a simulation project. These recommendations are not fully applicable to collaboration in the virtual simulation project. The new approach that combines the simulation life-cycle project methodology and virtual team methodology is being developed (Figure 4-1).

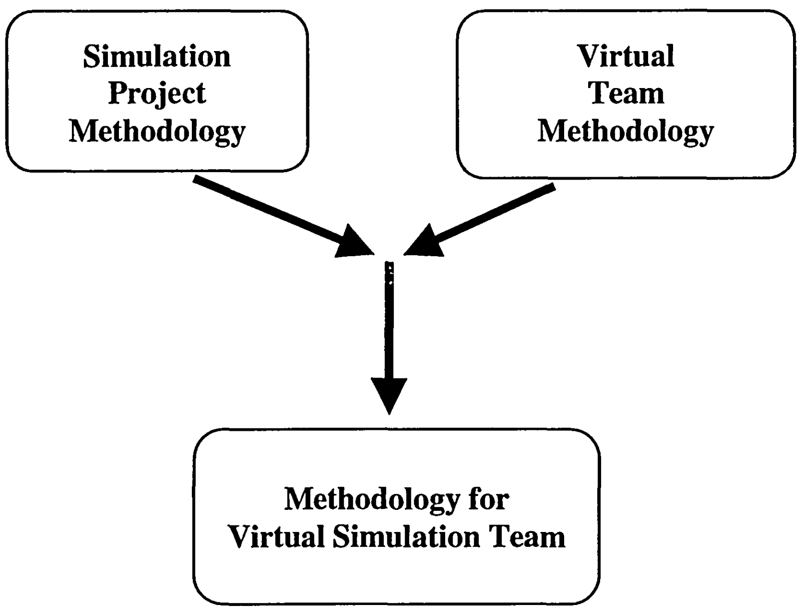

Figure 4-1 The new concept of Virtual Simulation Team Methodology

4.1 Definition of methodology

Avison and Fitzgerald (1995) define an information systems development methodology as:

> *a collection of procedures, techniques, tools, and documentation aids which will help the systems developers in their efforts to implement a new information system.*

Applying this definition to the virtual simulation project, the methodology developed in this research can be described as *a collection of procedures, techniques, tools, and documentation aids, which will help the people in their effort to effectively implement* *virtual teamworking in the simulation project.* A methodology will consist of phases and sub-phases, which will guide the people involved in the simulation project in their efforts to establish the techniques and methods that might be appropriate at each stage of the project. It will also help to manage, plan, control and evaluate virtual teamworking

According to Avison and Fitzgerald (1995) a methodology should specify:

- how the project is to be broken down into stages
- what tasks are to be carried out at each stage
- what outputs are to be produced
- when, and under what circumstances, they are to be carried out
- what constraints are to be applied
- which people should be involved
- how the project should be managed and controlled
- what support tools may be utilised
- how people should be trained and what are their training needs

These suggestions can serve as good guidelines for the development of the methodology, which should cover the entire life cycle of the implementation of the simulation project in virtual environments.

4.2 The rationale for a methodology

Avison and Fitzgerald (1995) identified three main categories of rationale development of a methodology: a better end product, a better development process and a standardised process.

1. A better end product - The methodology can improve the development process of the end product. It assists with the quality of the end product by considering a number of issues such as economy, effectiveness, documentation, flexibility, functionality, reliability, security, simplicity, compatibility, etc.
2. A better development process - The specified methodology can bring benefits that accrue from controlling the development process and identifying the outputs at each stage. This improves management and project control, allows us to build systems faster and allocate required resources.
3. A standardised processes - This category relates to the benefits of having a common approach throughout an organisation. This means that staff can easily change from project to project without need for retraining.

4.3 Developing methodology - background

Methodologies, as an effect of the research process described in Chapter 2, can be divided into two main categories:

1. Those developed from practise (inductive approach)
2. Those developed from theory (deductive approach).

The methodologies in the first category have typically evolved from usage in an enterprise and then been developed into a commercial product. Usually people find some techniques or methods more useful than others, and then they concentrate on developing the use and effectiveness of those techniques.

People from universities or research institutions have usually developed the second category of methodologies. These are usually published in books and specialised journals, and than have been applied by commercial organizations.

The author in this research deployed a deductive approach to develop methodology for applying the virtual team concept into the simulation project life-cycle. The extended literature review supported by discussions with simulation practitioners, management and IT people, as well as the author's experiences from number of simulation project allowed proposing and formalising a methodology for establishing a virtual simulation team.

4.4 Developing methodology for virtual simulation teamworking

Based on the literature research presented in Chapter 1 and Chapter 3 the author produced the list of important aspects that need to be considered in developing a virtual simulation team:

- Setting goals and objectives for the simulation team
- Team leader competencies
- Team members selection and their roles in team building and projects
- Selection of technology
- Team trust building
- Alignment of processes to the virtual environment
- Performance measures and reward system
- Members training
- Security issues

- Virtual team facilitator

4.4.1 Setting goals and objectives for the virtual simulation team

Having defined goals and objectives is one of the most important factors that contribute to the success of the virtual simulation team. The clarity of the goals implies that there are specific performance objectives, phrased in such concrete language that it is possible to tell, unequivocally, whether or not those performance objectives have been attained. The objectives and goals in a virtual simulation team must be related to an examination problem and stated at a measurable form, whenever it is possible, for example: increase efficiency by 10%, reduce cost by 5%, etc. If it not possible, for example increase knowledge about system's behaviour; the objectives must be phrased in such concrete language that it is possible to tell, unequivocally, whether or not those performance objectives have been attained. The virtual simulation team must clearly define their direction, including goals and objectives at the beginning of the project as lack of face-to-face contact makes it more difficult for virtual team members to stay in tune and aligned to the purpose of the team and allow avoiding future misunderstanding and conflicts in the virtual collaboration process.
Henry and Hartzler (1998) defined goals and objectives as panel statements of the desired end results with objectives that make clear the specific actions and activities needed to obtain them. They also point out that direction for a team is provided by four factors: mission, vision, goals and objectives. Haywood (1998) expressed the importance of a written statement of the project or team goals in evaluating team members for alignment to tasks.

4.4.2 Principled leadership

Considering the nature of the simulation project the leader does not necessarily have to be involved in the process of developing the simulation model. However, it is vital that the leader has knowledge concerning the simulation project life-cycle, and some general practise in the area of model developing.
However, the responsibilities of the virtual team leader are more complex as he/she needs to link the distributed people together in an efficient structure. The virtual team leader has to be competent in team performance management, people coaching, appropriate facilitate of communication technology, and be able to cross cultural and time barriers.

Developing the traditional superior leadership described by Kinlaw (1991) and attributes identified by Fisher & Fisher (1997) the virtual simulation team leader must:

- lead virtual simulation team players through the project and collaboration process;
- stay focussed on team development and improving performance;
- motivate team members and build their commitment to the project;
- develop trust building atmosphere;
- encourage and support people's development;
- manage team and team's players performance;
- support and promote the virtual simulation team through the company;
- manage by principles rather than policy;
- effectively coach individuals and teams;
- understand and communicate data and information;
- eliminate barriers to virtual simulation team effectiveness;
- stay focus on demands of the simulation project customer.

4.4.3 Members team selection and their roles in team building and project

The team members are the spine of the simulation project and they can be compared to machine parts that have to fit together and perform according to requirements. Since the simulation team consists of workers from different backgrounds (Chapter 1.5.3) it is important to look at extra competencies, which virtual team members have to acquire in addition to traditional team competencies such as self organization, the ability to learn and work in a virtual environment, to communicate clearly and efficiently, etc. Table 4-2 presents the activities in the recruitment process of the virtual simulation team members, while Table 4-1 presents competencies for effective virtual team members identified by Fisher and Fisher (1997), Duarte and Snyder (2001)

Competencies for knowledge virtual team members identified by	
Fisher and Fisher 1997	Duarte and Snyder 2001
Customer advocate Having strong awareness of the customer's wants and needs coupled with a strong desire to meet them	Project Management Planning and organising individual work to correspond to team schedules Developing and using method to report progress and problems Monitoring and controlling costs Taking action to get back on track Documentation and sharing individual learning
Trainer Showing a willingness to train and develop others by sharing knowledge	Networking Knowing the organizational landscape and who is in it Knowing what questions to ask to get other perspective Maintaining guidelines about when to see people face to face, when to send them messages, and when avoid them altogether
Resource Continually expanding personal knowledge and applying it to the workplace	The use of technology Using the appropriate technology to communicate, coordinate, and collaborate, given the task and the backgrounds of other team members Knowing how to access training or help with new technologies Knowing the etiquette of using technology Knowing how to plan and conduct remote meetings
Skilled worker Demonstrating the technical skills necessary to perform the job effectively	Self management Skill in establishing personal and professional priorities and goals Skill in prioritising work and setting limits Skill in creating and executing opportunities for individual learning and growth Skill in taking the initiative to change working methods and processes to meet the demands of the work
Team player Working and communicating well with other team members and business associates	Crossing boundaries Understanding how cultural perspectives influence work and collaboration Understanding how differences in national, functional, and organizational cultures impact working styles, team interactions, team-members' expectations, and team dynamics Being sensitive to differences in business practices in different parts of the world
Decision makers Being able to assimilate and utilise information for making decision that directly affect the team	Interpersonal awareness Being aware of interpersonal styles and their impact on others Collecting feedback on one's interpersonal style from other team members Discussing one's interpersonal strengths and weaknesses with other team members and provide them appropriate feedback on theirs Being able to plan experiences that lead to improvement
Problem solver Identifying and addressing problems that occur in the work area	

Table 4-1 Competencies for virtual team members

Phase	Activities
Developing a person specification	*Job analysis* - analysis of the job to identify the specific task the project entails and how the should be performed *Job description* - statement indicating the activities, responsibilities and expected standards of performance *Person specification* - qualification required of applicant
Recruitment and Selection	That part can be divided into advertising the job, application, references, and interview the applicants
Induction and Training	*Induction* - it is welcome and familiarization with the project and organization *Training* - it is introduction to technical skills and behaviours needed to perform their jobs effectively

Table 4-2 Activities in recruitment process

4.4.4 Selection of technology

The choice of technology has an important influence on effective communication in a virtual team. There are different tools available and a number of factors to consider. Because of that this aspect is presented extensively in a separate Chapter 1.7.

4.4.5 Team trust building

Trust is essential for a virtual simulation team to successfully complete a simulation project and for team members to feel satisfied with their work and the experience gained during the collaboration in the virtual environment. Trust is as a critical structural and cultural factor that influences the team's success, performance and collaboration and requires shared purpose, goals, commitment and locality across virtual teamworking.

According to Lipnack and Stamps (1997) teams with higher levels of trust unite more easily, organise their work better and quicker, and manage themselves. They suggest that trust has to be built immediately from the start of the project. Henry and Hartzler (1998) also pointed out that the best time for building trust is the beginning of a project and suggest that face-to-face meetings are the best and quickest way to do it.

The concept of building and maintaining trust in the virtual simulation team needs to be introduced at the first meeting, which in author's opinion (Chapter 4.6) should be a traditional face-to-face meeting. That gives the kick off to the project; introduces the involved parties and builds professional relationships. This involves a training session during which the people are taught about communication-collaboration rules, social and trust building behaviour (Table 4-3). Building trust also requires the use of mutually understandable, explicit language with specified etiquette.

However, trust building is an ongoing process that affects the performance of the virtual simulation team. It requires keeping appropriate levels and schedules of open communication. Team players should also try to maintain social interaction by exchanging non-project related information that ties team members together.

	Trust Factors
Performance and competence	Develop and display competence
	Follow through on commitments and show results
Integrity	Ensure that your actions are consistent with your words
	Stand up for your convictions; display integrity
	Stand behind team and its people
	Communicate and keep everyone informed about progress
	Show both sides of an issue
Concern for well-being of others	Help team members with transitions
	Be aware of your impact on others
	Integrate team needs with other team, department, and organizational needs

Table 4-3 Trust building behaviour (based on Duarte and Snyder 2001)

4.4.6 Alignment of processes to the virtual environment

To fully exploit the virtual environment there is a need to examine and evaluate processes in the traditional simulation project life cycle. That procedure includes not only the study of the stages of the simulation project, like collecting data, presentation of models and results, validation of models; but also the processes in team working, such as redesigning the meeting structure, developing a reward system, describing performance measures, etc.

4.4.7 Performance measures

Volkoff et al (1999) define three basic criteria regarding team effectiveness:

1. Team productivity level - this criterion is related to the team's actual performance -team output, product or service,
2. Ability to learn and improve its functionality - this is based on the process of conducting the work (not the actual outcome),
3. Members satisfaction level - this relates to the individual's feeling concerning teamworking and the project

There are many methods that can be used to characterise effectiveness within a virtual simulation team setting. It is possible to measure the simulation project's output by examining either objective reports that represent quantifiable data, or subjective perceptions that exhibit the level of quality. On the other hand, effectiveness can be also evaluated based on the process the team undergoes (Lurey & Raisinghani 2001). Campion et al. (1996) research showed that team member's perceptions can be valid predictions of the team's effectiveness since the team members are central to the work, and thus, they directly influence the team's productivity and satisfaction.

Whilst the outcome measure such as productivity or quality can be assessed after the fact, a process of measuring team effectiveness allows the assessment of effectiveness midstream, while the work is still being performed. In that case it is important to collect and analyse data concerning sub processes in the virtual simulation team and feedback from members of the team. At regular intervals, or after every virtual meeting, the team members must give information to the team leader about their perception of team effectiveness. One of the possible forms is to apply a WWW questionnaire.

4.4.8 Reward system

It is difficult to create an equalized reward system in a virtual simulation team given consideration that team members can be from different organizations with different compensation and benefit structures. It is important that people can identify project success with their own satisfaction and benefits. The virtual simulation team leader must support and promote team participants involved in the simulation project in order to recognize their contribution and service by management people.

However, Kohn (1993) proved that a substantial reward system shouldn't be based only on the financial aspect; there is a need to include non materials benefits such as, official praise from management, promotion, increased responsibility, etc.

4.4.9 Members training

The comprehensive training session is a critical success factor. The training has to include aspects such as technology, communication procedures and social behaviour. The people need to be trained to master the operation of virtual team systems, for example, how to use the conferencing system, where to look for information, how to contact other members, etc. However, there is a need to develop and introduce the appropriate social behaviour, such as how to join or leave virtual meetings, how to formulate questions and opinions, what sentence to avoid, how to maintain dialogue, etc.

4.4.10 Security issues

Without adequate security measures, organizations resist connecting their corporate information systems to the virtual team systems. There are obvious confidential requirements concerning access and exchange of data with the outside world. The other issues concern security of data and company servers against attempts of computer hackers.

4.4.11 Virtual team facilitator

Duarte and Snyder (2001) highlight the need for creating and supporting policies that provide technical support for remote teamworking, which should provide team members with equal and immediate access to communication and collaboration devices, training and technical aspects. However, Bal and Teo (2001) point that policy alone does not suffice for effective team facilitation and propose a virtual team facilitator to link the virtual teams to the resources and skills within each organization.

The virtual team facilitator supports the virtual team in day-to-day matters concerning communication, allocates and maintains the team's resources, data and document transfer, training, and technical questions. However, his role is also to stimulate and guide a discussion, keep the simulation team focussed on their objectives, hold and distribute a track of teamworking, etc.

4.5 Develop the framework for effective simulation virtual teamworking

The extended research in the area of virtual teamworking, and years of experience in the simulation project life-cycle, allows the development of a model, which can be used as a framework for the methodology for virtual simulation teamworking. The presented approach evaluates Bal & Gaundry (1999) proposals for virtual teamworking in the automotive supply chain. However, the simulation project life cycle requires a different approach because the success of the project depends strictly on a simulation model development and performance. In this case the framework has to focus on the simulation model development and take into consideration the process and people involved in it. The new proposal is composed of four main factors: simulation model, teamworking processes, people and teamworking, support technology. The model presented in Figure 4-2 also identifies 16 key features for the successful implementation of virtual teams in simulation projects.

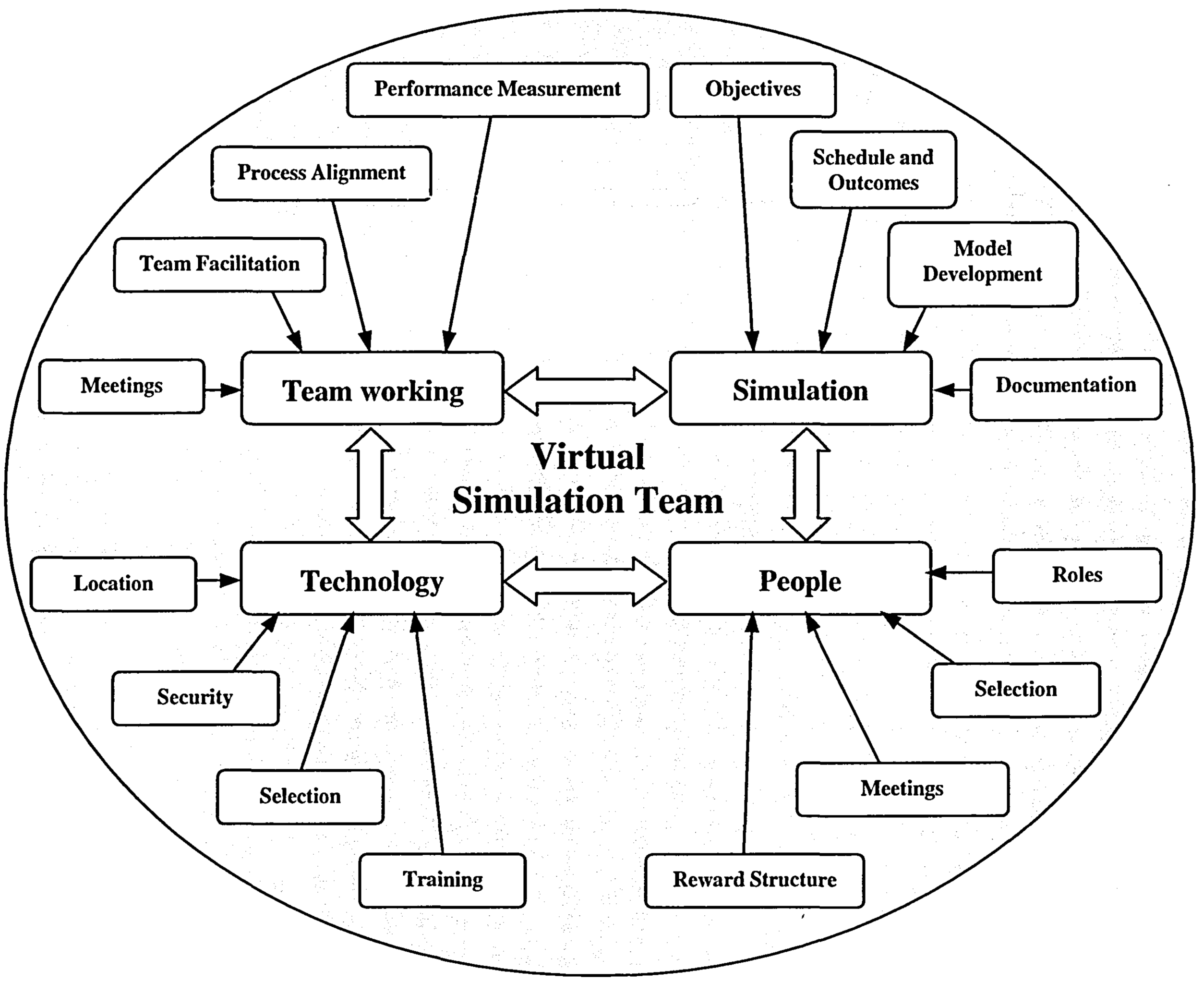

Figure 4-2 Important factors for successful implementation of virtual teamworking in a simulation project

4.5.1 Team working factors

The cooperation processes in the traditional simulation project are developed in consideration of the needs of face-to-face meetings. In this case to obtain benefits from virtual teamworking implies redesigning processes to suit the new reality.

Meetings

According to Duarte and Snyder (2001) the virtual meetings require a more formal structure in comparison to traditional meetings. There is a need to establish social convention - etiquette to effectively facilitate virtual meetings. The guideline has to describe how to start a meeting, join or leave the discussion, record output, etc.

Team Facilitation

Virtual teamworking allows people to work on a greater number of projects involving external collaborators (Chapter 4.4.11). According to Bal and Gundry (1999) there is a need for a virtual facilitator, whose role would be to allocate resources and provide technical support for team members.

Process Alignment

It requires an examination of the processes in traditional simulation projects and adjusts them to virtual teamworking (Chapter 4.4.6). That implies redesigning processes such as data collecting, model validation and verification, presenting models and results, collaboration and communication.

Performance Measurement

It is essential to measure the individual and team performance to provide feedback to team members and management. It also allows spotting any problems in teamworking and keeping track of work and progress in the project (Chapter 4.4.7).

4.5.2 Simulation project factors

Simulation project life-cycle methodology ought to be used as a strong guideline for developing the virtual simulation team, which must be focused on developing the simulation model, and concentrate its efforts in that direction. The simulation project indicates the life-cycle of virtual teamworking, requirements for team members and specifies objectives.

Objectives

The objectives of the project have to be clearly stated, and formed in a way that allows measuring whatever they are accomplished or not. The properly identified and described objectives can be a focus point and guideline through the work (Chapter 4.4.1).

Schedule and Outcomes

Virtual teaming requires a tightened schedule of the project, which needs also to include time for regular virtual meetings. The expected outcome for every stage of the simulation project allows keeping track of the project's progress.

Model Development

Virtual collaboration allows the client and/or model end-user more active and regular participation in model development, especially in decisions such as model details, model verification and validation, designing experiments, etc (Chapter 1.3).

Documentation

The virtual environment brings a new opportunity to publish project documentation, which includes virtual teamworking data and simulation model description. The team members need to have constant access to on-line documentation.

4.5.3 People factors

Transforming from traditional simulation teamworking to virtual teaming effects the way the simulation project is carried out, it also changes the interaction between team members. Virtual working requires a different approach from project participants with consideration of these four factors: members' roles, people selection, meeting behaviour and reward structure.

Roles

The simulation project life cycle implies the seven basic roles (project leader, client, model builder, model end-user, data provider and modelling support) which are presented in

Chapter 1.5.3 - However, for the purpose of virtual teamworking, the addition of a team facilitator who would be responsible for the technical issues of virtual teamworking is widely accepted. The clear specification of roles and responsibility would help to avoid misunderstanding and mistrust during the project development.

Team's Members Selection

Virtual simulation teams are made up of people from different departments in an enterprise or from different collaborative partners, which bring a mixture of work organization and culture. Managers selecting team members have not only to consider experience, knowledge and availability but also put extra stress on people's ability to work in the virtual project. They must take into account self organization and self motivation as the team members work mainly in isolation, with a high degree of autonomy. These people should also present a willingness to learn and play with new communication technologies.

Meeting Behaviour

Team members must be aware that virtual meetings require a different approach than traditional face-to-face interactions. People need to be taught how to communicate efficiently, for example by conducting a running dialogue, shown the restrictive aspects of the virtual teamworking technology employed and highlight the methods to fully exploit its benefits.

Reward Structure

The reward structure should focus on the team performance rather than on individual performance. However, it means that people have to be aware of their influence on team performance and the success of the simulation project (Chapter 4.4.8).

4.5.4 Technology factors

Virtual teamworking is based on the appropriate utilization of technology to support the communication and data exchange between team members. They can use various communication technologies during the simulation project life-cycle to follow the work and keep in touch with each other. Depending on requirements, these can range from telephone, email, video conference to a professional workgroup support system with data exchange system and integrated database system. However, according to Bal and Foster (2000), this does not mean that the organization requires to use all the best technology available to implement virtual teamworking, more attention should be paid to cross-cultures in order to communicate effectively with the minimum of cost and effort.

Location

The organization can create a special room for the virtual meeting or deliver the technology to the desktop computer of every player in the team.

Security

There are two kinds of issues associated with security in virtual teamworking. First is the requirement to share corporate information among collaborative partners. The second is more general, and related to the safety of the organization's information system against any attempts to break into it by hackers.

Selection

The tasks, organizational capability, cost and user skills are the factors that the selection of technology ought to based on. At the second level the effectiveness of technology, richness of information and level of possible interaction between team members.

Training

To exploit the technology people have to master the operation of virtual team tools. The training sessions need to introduce communication technology and etiquette, but also explain how and where look for a support during teamworking.

4.6 Methodology for carrying out a simulation project in a virtual environment

In a simulation project, the simulation team members need to manage technical work as well as the project in which the work is being done. Figure 4-3 shows two parallel loops, where the first one is connected with the development of the simulation model based on Pidd (1998), and the second one concerns the virtual team working - project side.

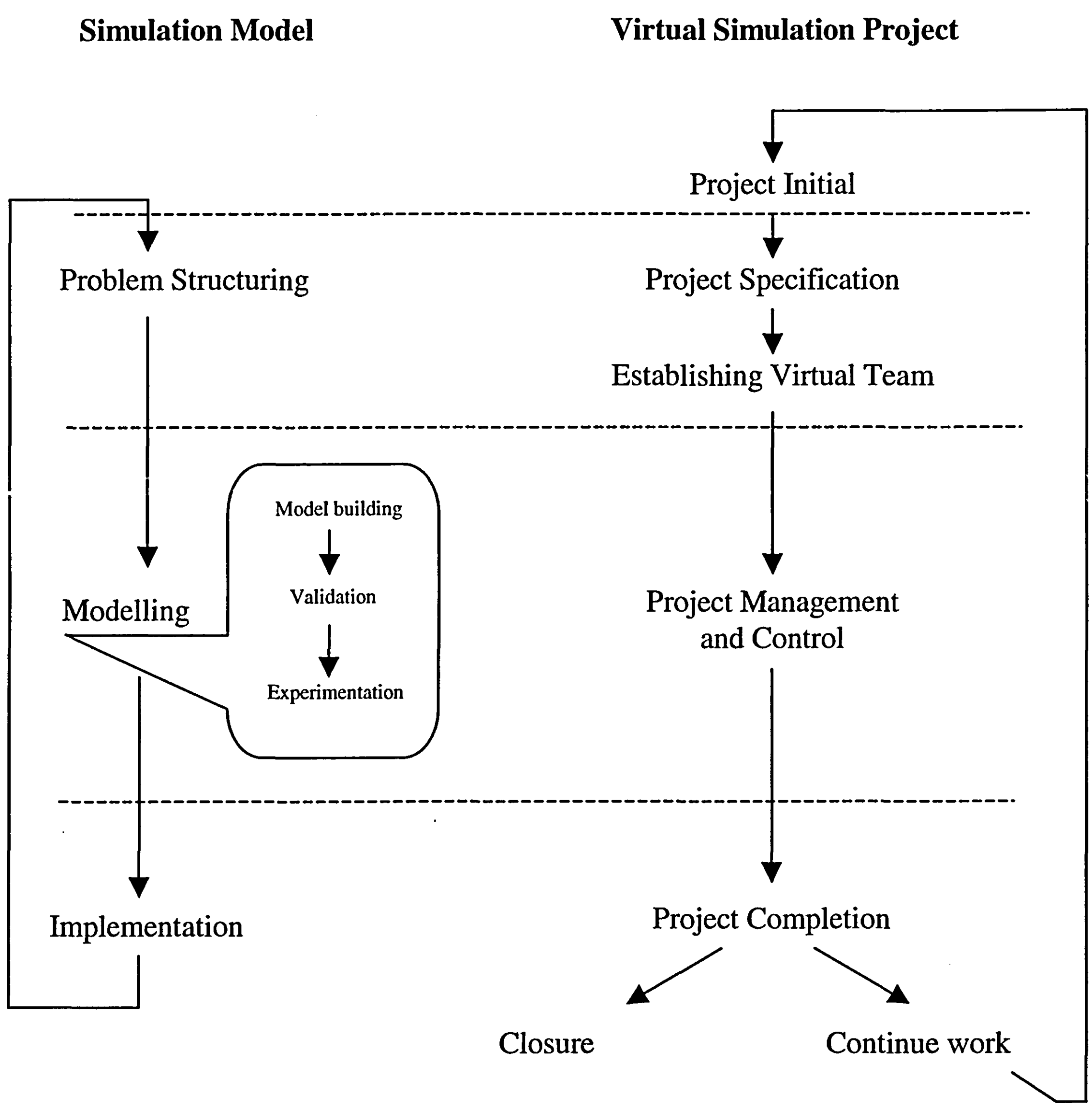

Figure 4-3 Streams in simulation project

4.6.1 Development of the simulation model

The left hand side of Figure 4-3 covers the technical work carried out during the simulation project life-cycle concerning the simulation model. Pidd (1991) distinguishes three main phases in the process of the development of the simulation model:

- Problem structuring - this is the attempt to formulate the requirements and condition for the simulation model
- Modelling - this is the essence of every simulation study and involves the use of computer and statistical methods to develop a simulation model and analyse simulation results. It is divided into model building, model validation and experimentation.
- Implementation -this is the effort to put into practise any recommendations that emerge from problem structuring and analysis.

The process of developing the simulation model is more widely discussed in Chapter 1.3, where different simulation project life cycle diagrams are presented.

However, for the purpose of virtual simulation teamworking, the process of model development does not change. Generally, the practise and methods are the same while there are modifications in model presentation and validation. The model ought to be presented, reviewed and validated by other team members on a regular basis using communication technology. It consolidates the team, increases trust in teamworking, as well as raising the awareness of simulation between people and increase confidence concerning the final results.

4.6.2 Development of a Virtual Simulation Team

Apart from the technical work in which the analyst must engage, it is the simulation team by which the work is managed. This section reviews some aspects that are relevant to virtual simulation projects, the main stages of which are shown on the right hand side of Figure 4-3.

As the simulation team members have clearly defined roles (Chapter 1.5.3) and the simulation project lifecycle is divided into natural stages (Figure 1-1, Figure 1-2) the virtual simulation project can be divided into three main stages (Figure 4-4):

1. Organisational stage – In most cases there is the first meeting when the objectives of the project are set up, the simulation team is formed, the rules depicted and organisational problems solved for virtual teamworking.

2. Collaboration stage – This is the time of collaborative working to manage to finish the project successfully. It is based on a daily or weekly virtual meeting to discuss the project.
3. Project completion – The project is summarized, documentation created, solutions proposed and recommendations for implementation prepared.

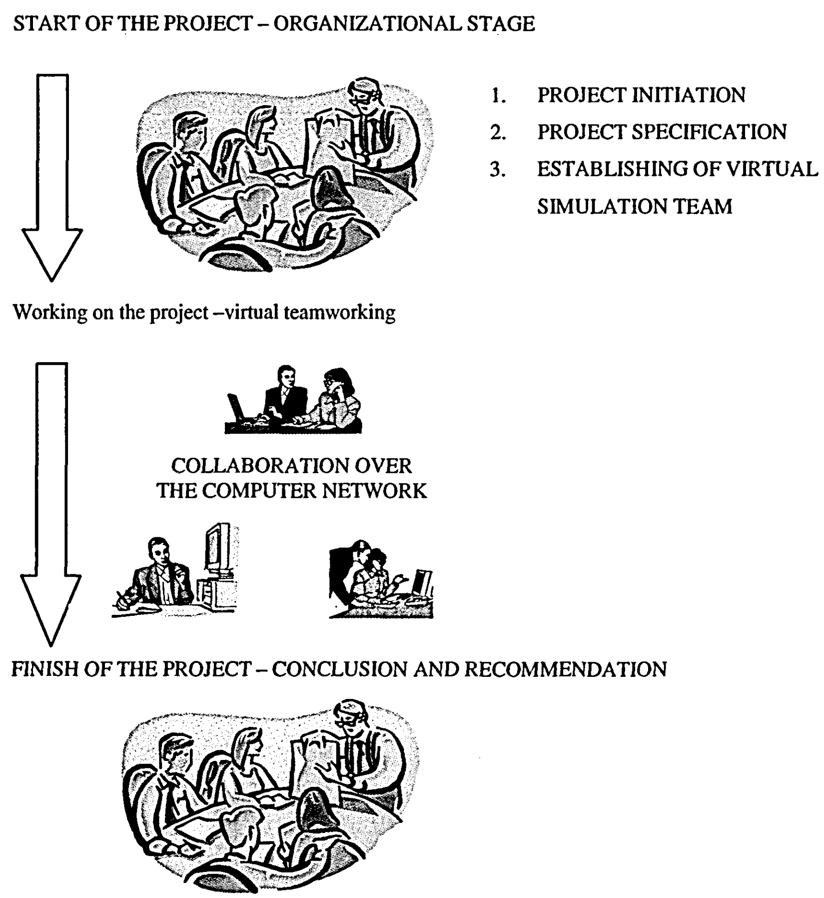

Figure 4-4 Key stages of virtual simulation teamworking

4.7 Project initiation

The aim of this phase is to find a consensus between all the individuals involved in the study. The fundamental aspects of the project such as budget, expectation, schedule and resources have to be discussed. A contract that describes and supports the following cooperation is produced as the result of this stage.

4.7.1.1 Project Specification

During this stage a detailed project specification is created that covers such things as:

- Identifying the objectives and purpose of the project
- Specifying the conditions under which the model is to be used
- Describing the initial level of simulation model details
- Defining the time-scale for the project and creating a schedule of work
- Identifying the resources needed for the purpose of the study
- Describing the collaboration rules, etc.

This stage is closely correlated to next one - establishing the virtual simulation team, and in many cases is carried on simultaneously.

4.7.1.2 Establishing the Virtual Team

The human resources are set up, grouped together and the team is formulated. For the purpose of the study, as well as, specifically, of a simulation study, it is preferable that the first meeting ought to be face-to-face. There are two main benefits of this:

1. Formulation of the virtual simulation team - it allows, for the first time, gathering team members together to get know each other, build trust - establish foundations for future virtual cooperation. That meeting can be used to assess training needs, introduce people to the tools, rules and concept of virtual teamworking.
2. Initiation of simulation project - it concerns the discussion about the project issues, sets up requirements and expectations of the team members, familiarises them with simulation tools, methods and project life-cycle. That includes the possibility of visiting and inspecting the real system, of course if the system exists.

4.7.1.3 Project Management and Control

According to Pidd (1998) there two key elements in managing and controlling a simulation study:

1. Managing the expectations of the various parties involved in the project - That is why it is so important to create the initial project specification.
2. Coping with the dynamic progress of the project - That refers to the progress of the simulation model development as well as the cooperation and collaboration in the virtual simulation team.

The initial project documents must specify the milestones and schedule of the project so it is possible to review the progress of the project and intervene in case of any problems. However, the virtual simulation team can face twofold challenges during the project's advance: firstly, creating the simulation model, Secondly, virtual teamworking.

The simulation model development involves collecting and analysing large numbers of data, which is sometimes not available when needed, or may turn out to be faulty in one way or another. In extreme cases the project needs to be reviewed and a new project specification created, or in others the solution appears only after a thorough analysis of the input data. The availability of input data can determine the level of model detail. The outputs of the simulation model or experiment are not unequivocal and the model needs to be reviewed and/or more experiment carried on. For that reason, it is advisable to review the simulation model at the virtual team meetings to spot the potential problems at an early stage.

The final success of the virtual simulation project strongly depends on the team leader and his/her management skills to control the virtual team. The team leader, with the support of technology, has to organize teamworking, solve conflicts and build trust, motivate and support team players, stimulate discussion and generate ideas.

The virtual meetings need to take place on regular basis based on the schedule of the project. Participants ought to get access to the meeting agenda and materials before the actual event to prepare themselves and state precisely their opinion. The meeting agenda should allow time for presentation and discussion so that every team player can take a part on an equal footing. The meetings need to be summarized, documented, and output data made available to team members.

4.7.1.4 Project Completion

Final results of the project can lead to either of two routes - finish, or carry out more work. The results have to be reviewed against objectives and the specification of the project and the decision to continue or close must be decided. Independently of that, the project must be documented, guidance how to implement the results, and eventual future work established.

4.8 Redesigning the meeting structure for virtual simulation teams

Meeting behaviour in virtual meetings ought to be considerably different from face-to-face meetings. Experts' observations have shown that that the virtual team leader has to be more planned and structured in their team coordination effort (Duarte and Stamps 2001, Lipnack and Stamps 1997, Bal and Teo 2001). Moreover the team leader needs to check that the communication links work correctly before the start of the meeting. Effective virtual communication requires a different approach to guide discussion, formulate questions and obtain feedback. For example, it is better to be more specific, for example "What do you think about idea from page 5, line 20?"

However, there are more aspects to consider making the virtual meeting as effective as traditional face-to-face collaboration. Those features can be divided into short, medium and long-term recommendations (Figure 4-5).

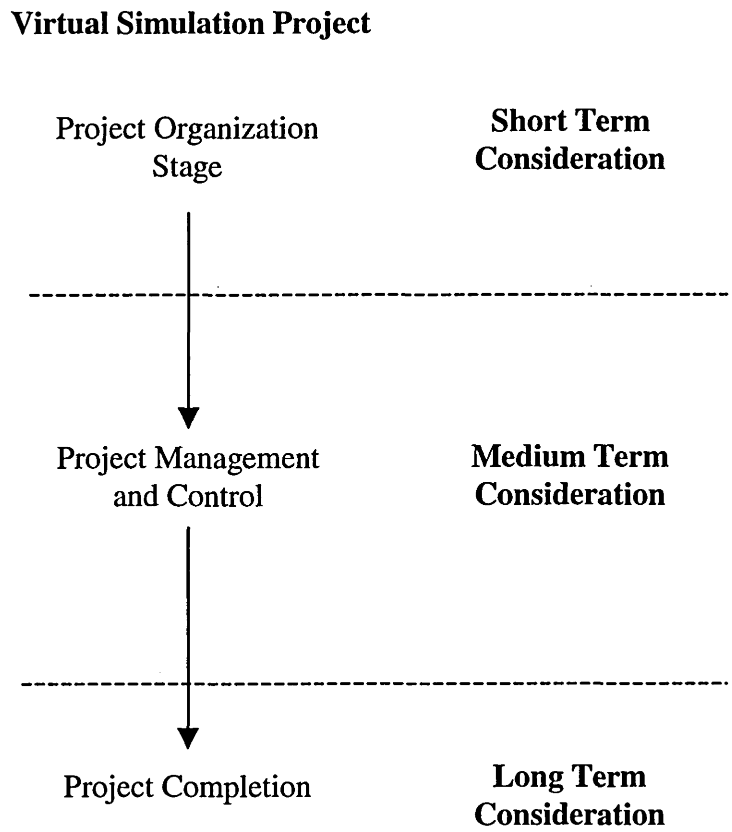

Figure 4-5 Recommendation for Virtual Simulation Project

4.8.1 Short term recommendation

For a simulation virtual team it is advisable to get all the team members together in traditional face-to-face meetings to start the project and to discuss the collaboration issues. The team members are introduced to some best practise for the virtual meetings, communication rules and conventions, sort out meeting arrangements and technology issues.

Below is a list, which provides examples of questions to consider:

How to arrange a virtual meeting?

Who and when to provide training?

How to schedule meetings?

Who will facilitate meetings?

How and who shall contact participants?

Who will check technology resources available for team members?

How to check the communication technology?
How to determine what communication tool will support the purpose of the meeting?
How to determine if there is a need for additional support tools such as shared whiteboards, database or decision support system?
How to exchange documents and present information and documents?
How to create a meeting agenda and how allocate time for each point of the agenda?
How to guide discussion?
What is the convention for people to join or leave the virtual meeting?
How to check if the participants have the right software and hardware for the meeting?
Do the players know the best practises how, when and where to allocate the technology?
How to communicate and inform team members?

4.8.2 Medium term recommendation

When the simulation team has been developed the set of procedures and guidelines are created for an effective virtual meeting. However, there are some extra considerations required when the project is carried out, such as:
How and who is responsible for maintaining the project documentation, database, software and hardware?
Who is responsible for providing technical support?
Who is responsible for distributing documents and data between team players?
How to confirm receiving information?
When the meeting involves participants from outside the simulation team, how and who sets up procedures to apply and determine technology?

4.8.3 Long term recommendation

The experience and guidelines obtained during the virtual project can serve as directions to apply virtual teamworking across the organization. The company ought to create standardised guidelines and procedures that are applicable to all types of projects and virtual teams established in the future.

4.9 Validation of the methodology

However, the proposed methodology for transforming a simulation team into a virtual simulation team needs to be validated. In the examination process two validation methods have been developed:

1. Analytical methods (Chapter 7) - Simulation models were applied to compare the effectiveness of different collaboration scenarios in a simulation project. Simulation allowed analysing measurable factors such as a project cost and time.
2. Empirical methods (Chapter 6) - Following the recommendation presented in the previous chapters a virtual team has been created to confront a real problem using simulation models and developed technology. The experiment also allowed obtaining immeasurable data concerning human factors (social aspect). However, the empirical experiment required the building a support application that could be used as the communication medium in the daily base collaboration process (Chapter 5).

5 Developing technology for support virtual simulation team

The chapter 1 described the technology, which supports the virtual teamworking. However, this chapter presents the procedure used to develop an application for supporting a virtual simulation team. The applied life-cycle of software and information system development is discussed and appropriate methodologies and frameworks for planning, controlling and executing projects are introduced. The next part of the chapter follows the information system development life-cycle. First, the system's requirements are described, a project of application is proposed and the system's components are introduced. The last part describes the development of the particular components - applied methods, tools, and software to obtain functional application.

5.1 Introduction

The development of an application involves a number of phases, which are referred as the product development life-cycle. However, the literature research has shown that authors present different approaches to the system development life-cycle. In this project a straightforward, five-part life-cycle was applied (Figure 5-1) proposed by Capron (1986). Avison and Shah's (1997) life-cycle diagram among other similar stages included the review and maintenance of the final product.

However, the development process is in its nature iterative, and the borders between particular stages are not strictly established. People recognize that sometimes the previous stage must be reviewed and adjusted to a new situation or findings. Then the whole process can be repeated until a satisfactory output is obtained.

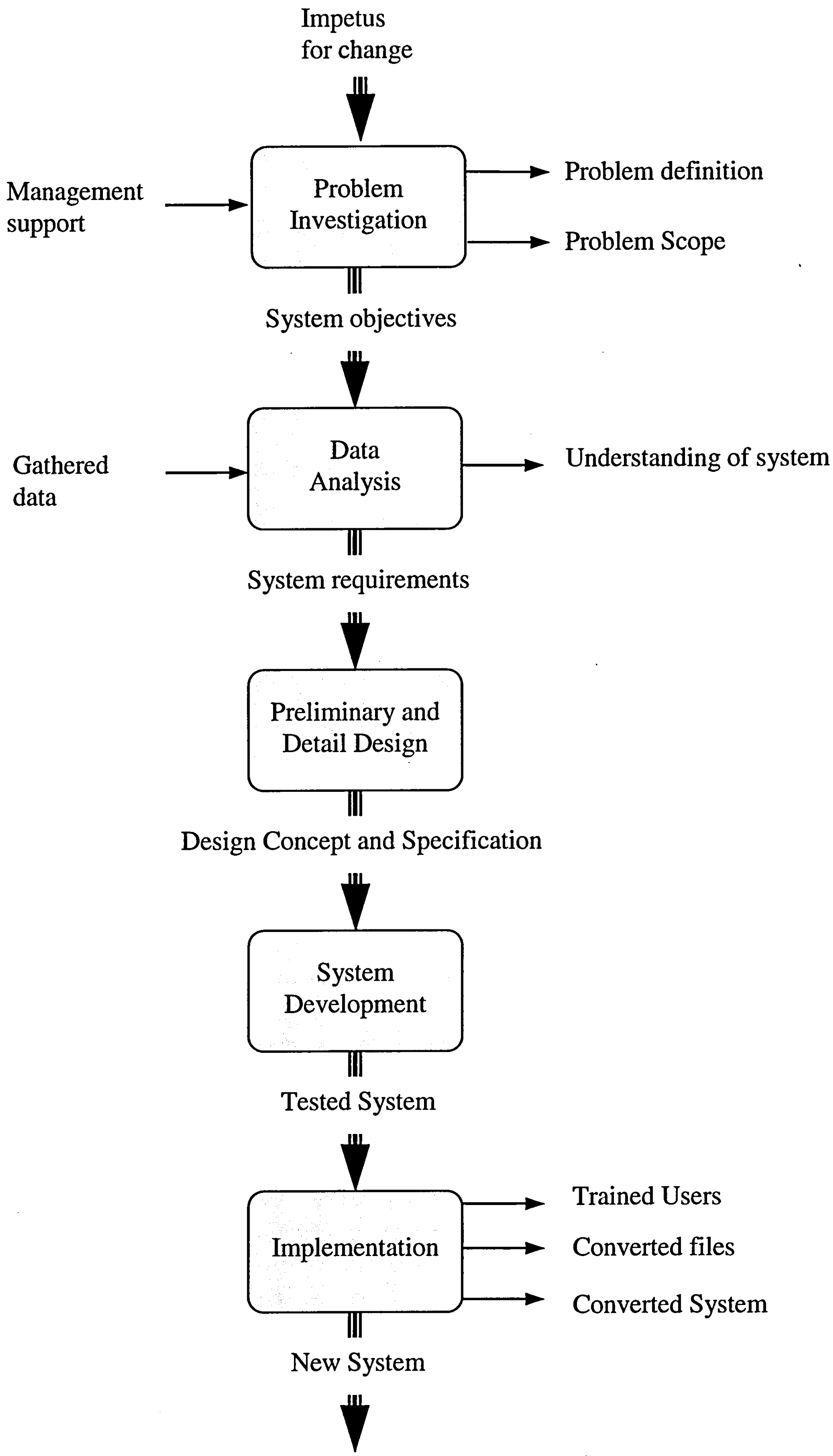

Figure 5-1 Systems development life cycle (based on Capron 1986)

5.2 Preliminary investigation - Determine the problem

The idea of preliminary investigation, sometimes called a feasibility study or the system survey, is to define the problem and recommend a solution.

5.2.1 Impetus for change

The simulation software has become more sophisticated, user friendly with built graphical interface, which makes the development of the simulation model faster and easier. However, the simulation project involves a number of people from different backgrounds and geographical locations. That increases the total cost and difficulty in forming a efficient simulation team and finishing the project in a short period of time. The simulation project may benefit from modern communication technologies and virtual teamworking philosophy. That implies the reduction of no-add-value cost such as travelling, better utilization of resources, shorter project's completion time.

5.2.2 Management support

Changes in working practices need to be approved and supported by management staff. The new proposal may directly engage managers and/or require the financial support to start up the project. The initial document/presentation must be prepared, which includes problem description, project implementation cost, resources, potential benefits and savings - These are presented in the next three following sub-chapters: 5.2.3, 5.2.4, and 5.2.5

5.2.3 Problem definition

The problem is to develop an application that will allow moving the simulation project into the virtual environment. The software must fulfil the requirements of simulation team to collect and exchange data, present, execute and validate simulation models. It also has to establish an efficient communication link between the project's participants, which allow forming a virtual simulation team.

5.2.4 Problem Scope

The problem focuses on particular areas of simulation project and team working:

- communication

- data collecting and distributing
- simulation model validating and executing
- collecting project documentation
- support team working

5.2.5 System Objectives

The simulation project life-cycle (Chapter 1.3) and virtual teamworking technology (Chapter 1.7) imply the following system objectives:

- Establish virtual simulation team
- Allow efficient collaboration between project's participants
- Allow conducting stages of the simulation project via the virtual environment

5.3 Analysis - Understanding the system

Extensive research on the problem and analysis of existing system and gathered data gave understanding of the situation and establishing system requirements.

5.3.1 Gathered data

Through extensive research on simulation technology, virtual teamworking technology, the communication technology, the computer development technology provides data to create system requirements and helps to understand the concept and structure of the solution.

5.3.2 System requirements

The author believes that system requirements can be considered from three aspects:

1. User - the system ought to be easy to learn and use; it has to allow people to fully participate in teamworking from remote locations, people must have the possibility to communicate, collect and review data, discuss and generate ideas, etc.
2. Technology - easy to create, install, and maintain; it should use standard solutions, which facilitates future developments; if possible it should be platform independent; it has to efficiently support the virtual simulation team and fulfil the requirements of the simulation project in communication and simulation model development, it must support data collecting , analysing, and reviewing, etc.

3. Company - minimise the total cost of the solution; possibility of upgrading and further developing application in the future, appreciate level of date security.

In author opinions the most important factors are the total cost of application, which has to establish an efficient environment for virtual collaboration, exchange simulation data tool, execute and present simulation models and results. At the same time the application ought to be user friendly, easy to learn, maintain and use. It should be also possible to tailor and upgrade application. The importance of team data security is also highlighted.

Table 5-1 summarised the importance of the particular requirements, which highlights the key requirements for system design.

Requirements	**Importance**
The total cost of developing the application	+++++
easy to learn	+++
easy to use	+++
easy to install	++
easy to maintain	++++
easy to tailor and upgrade	+++
establish efficient communication link	+++++
create collaboration environment	++++
platform independent	+
standardised solution	++
review the simulation model	+++
execute the simulation model	++++
collect and review data	+++
easy to develop	++
secure	+++++

Table 5-1 Analysis of the general application requirements

5.3.3 Understanding of the system

Virtual teamworking allows decreased costs of maintaining the simulation team and collaborative working. However, research concluded that the professional software to establish communication and collaboration between members of the team is very expensive. Users need to have compatible hardware and plenty of training. Therefore only a company with a large investing budget and an established teamwork philosophy can afford to buy and maintain professional software for virtual teams, such as the Electronic Meeting System. In order to reduce the technology cost in the virtual simulation teamworking it was decide to develop user-friendly, cost effective Web-based application for supporting the simulation team during the simulation project life-cycle.

The proposed toolkit for supporting virtual work on simulation projects has to combine the project management facilities with simulation and communication tools. The Web-based solution gives the users access to the application from anywhere in the world using a common Web browser. The application ought to provide the framework for supporting the simulation team in its day-to-day activities - communication, collaboration, exchange and collect data, create project documentation.

5.4 Design - Plan the new system

During this stage a project of the system was developed to meet identified system requirements. In the first step the preliminary design was created. Then in consultation with the customer and end-user the details design was developed and agreed.

5.4.1 Preliminary design

During this stage the strategic decisions have to be taken such as computer platform, programming methods or language. These and other aspects are discussed below.

Concluding the review of the literature the Web-based server/solution is proposed to maintain virtual teamworking and carry on the simulation process life-cycle. The WWW technologies in contrast to specified solution created from scratch, or other platforms have got advantages such as:

1. Platform independent – web-based application can work on different computer systems,
2. Easy to use and navigate thanks to the hyperlinks technology,
3. Common and popular,
4. Many applications or components are freely available on the Internet.

There are a number of commercial applications available on the IT market. However, there are significant differences in scope, price, portability and user friendliness. The new observed trend is a migration to utilize the popular Web technologies. Application of the

WWW technologies allow significantly reduced costs of development of applications as well as establishing a virtual team. Table 5-2 presents a comparison between Web technologies and professionally specified systems like NetMeeting, etc.

	Common Web technologies	Specialised System
Common Standards	YES (TCP/IP, HTML…)	No common standards
Data Handling	By unique URL	Proprietary
Information Structure	Tree structures and lists	Complex
Navigation	EASY	Depends on System
Specialist Knowledge	NO (only reading and clicking)	Depends on System
Easy to use	YES	Depends on System
Cost	LOW	HIGH
Platform Independent	YES	Depends on System
Popularity	VERY HIGH	LOW

Table 5-2 The comparison between Web and specialised solution.

The development in technology, such as new servers, faster network transfer, better data compression protocols, etc.; and expansion of new, more flexible programming languages such as JAVA, PHP, etc. allow creating the Web-based applications, which are even more powerful, and at the same time user-friendly. The advantages of Web-based solutions are proved, but the question remains how the WWW application for applying the virtual simulation team concept into the simulation projects life-cycle should look and what they should contain.

In conclusion if a simulation project is carried on in a virtual environment there are additional factors to consider, associated with information distributing, communication, collaboration and relation between team members, data management, remote model execution, etc. It is recommended that the simulation group needs to establish their WWW server to fulfil their demands. From programming experience it is required that the application should be built using component technology, which is easier to maintain, upgrade, and develop. The main part of the solution will be the WWW server and database. The WWW contents will be dynamically generated based on information collected in the database.

However, considering findings described in Chapter 1 and Chapter 2 it can be concluded that there are four main aspects to consider:

1. Distribution models, results, documents, etc. The server needs to allow presenting information connected to the project and teamwork, and as well as distributing documents and information between team members.
2. Communication and collaboration. The server must satisfy team needs for synchronous and asynchronous communication and collaboration, which is vital for the success of the simulation project.
3. Remote execution of simulation models. It will reduce maintenance costs of simulation software. It also improves models management and increase access to them via the computer network.
4. Collects data. Precision of simulation results strictly depends on the quality of data used in the simulation process. The server's software should allow collecting, validating and storing all data related to the simulation project and simulation techniques for future exploration. It will allow the creation of a database of knowledge

5.4.2 Design Concept

Concluding the primary design the WWW-based solution is proposed to carry on the virtual simulation teamworking. The design system consists of WWW-server with database, four modules responsible for distribution data, collecting data, model execution and communication; and simulator. Figure 5-2 presents the concept of the system and the next subchapters discuss the particular parts.

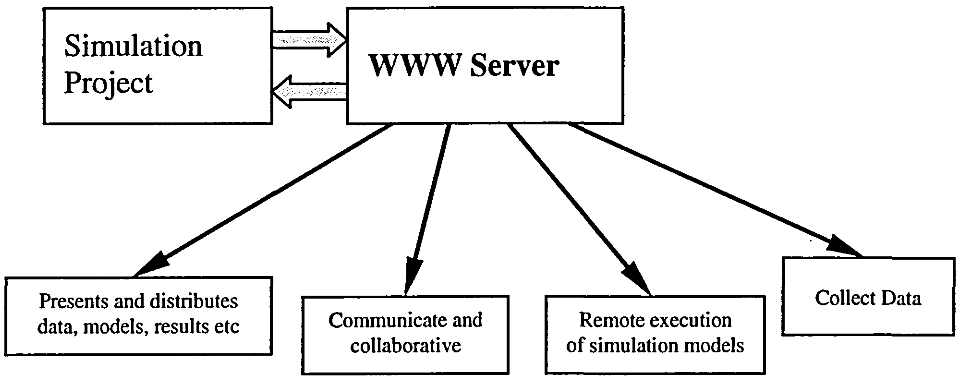

Figure 5-2 Structure of application

5.4.2.1 Requirements for management data system and project documentation

In the process of the simulation project life cycle various types of data are required. They were divided into two categories:

1. Data directly connected to the simulation project –these are quantitative in nature, for example cycles times, arrival rates and resources requirements, they explain logic rules such as control flows, scheduling and work allocation, etc.
2. Data indirectly connected to the simulation project – these are general data and materials about the project and simulation methodology, for example information from publications, data from consultants, materials relative to simulation and teamwork as outlined from meetings, decisions, work schedules, etc.

However, from a simulation project life cycle view (Chapter 1), the requirement data can be determined by:

1. Building the simulation model
2. Setting the initial level of the experimental factors
3. Checking the validity of the model
4. Co-ordinating teamwork

The simulation team should have access to database technology that would organise all kinds of data implicated in the simulation process life cycle. Laudon (1994) says that a database is a collection of data organised to serve many applications efficiently by centralising the data and minimising redundant data. The database was installed and configured to service multiple applications even through the Internet connection. In Figure 5-3 the database concept in the simulation project life cycle is illustrated.

5.4.2.2 Database Management System (DBMS)

A database management system (DBMS) concept is used to permit a simulation team to centralise data, manage it efficiently, and provide access to the stored data by application programs and users. The DBMS acts as an interface between user's application programs and the physical data files, which is illustrated in Figure 5-3 and Figure 5-4. When the user or application program calls for a data item the DBMS finds this item in the database and presents it to the user or application program.

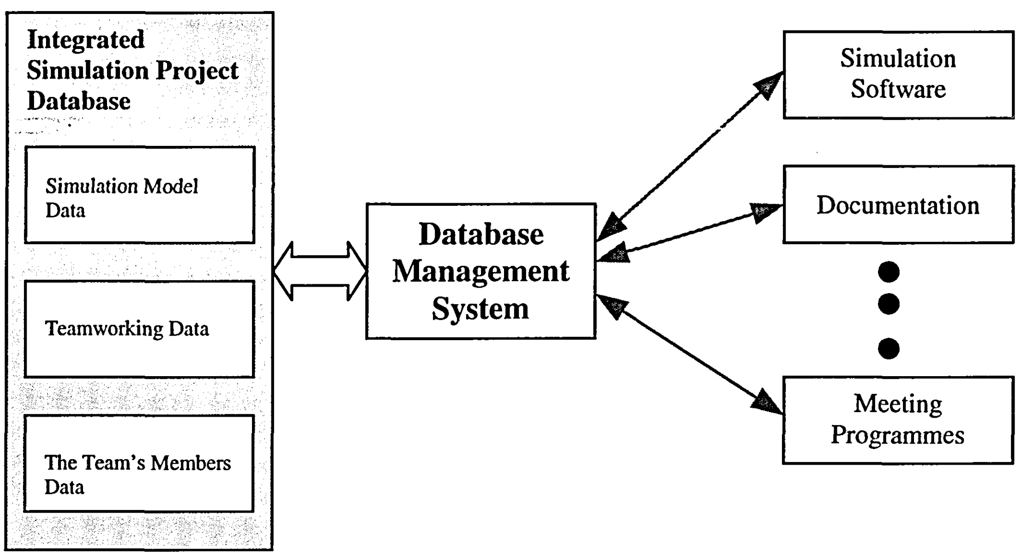

Figure 5-3 Database environment

Applied DBMS is made of:

1. A data definition language – the script language PHP was applied, which is executed on the WWW server side and is compatible with most of the WWW servers. The general programming language Visual Basic with Object Database Control (ODBC) is applied to connect simulation models with the database.
2. A data manipulation language is a specialised language used in conjunction with some other programming languages to manipulate the data in the database. The application

used most prominently for data manipulation language - SQL (Structured Query Language), which contains commands that permits the user to efficiently extract and manipulate data from the database to satisfy information requests.

It is anticipated that in an ideal database environment for a simulation project life cycle the data in the database is defined once and consistently, and used for all applications whose data reside in the database. Data elements called for by the application programs are found and delivered by the DBMS. The programme does not have to specify in detail how or where the data is to be found.

The advantages of a DBMS in simulation project life cycle are:

1. Central management of data storage, access, utilisation and security can reduce the complexity of the simulation project information system.
2. Eliminating all of the isolated files in which the same data elements are repeated can reduce data redundancy and inconsistency.
3. Providing central control of data creation and definition can eliminate data confusion.
4. Separating the logical view of data from its physical arrangement can reduce program date dependence.
5. Software development and maintenance costs can be reduced.
6. Access and availability of information can be increased.

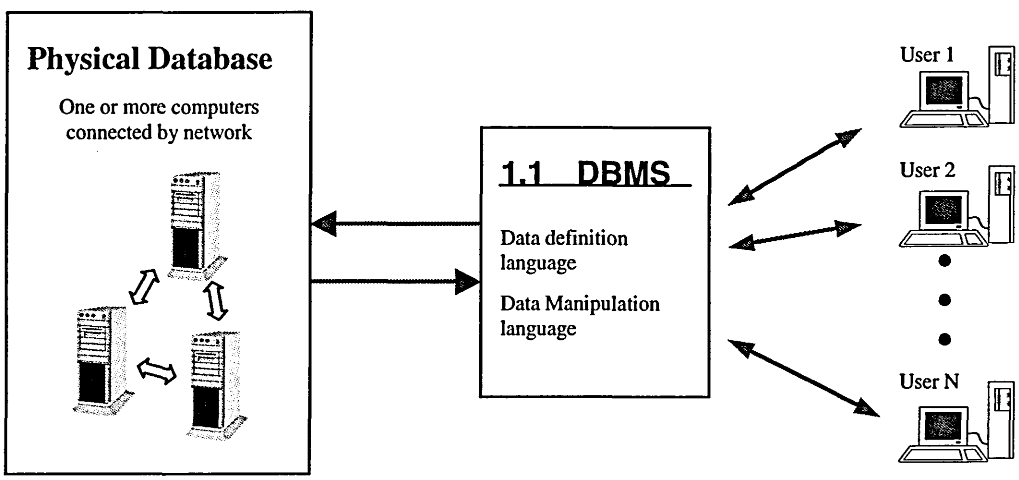

Figure 5-4 Elements of database management system

Flexibility of information systems can be greatly enhanced by permitting rapid and inexpensive ad hoc queries for information.

5.4.2.3 Data distribution

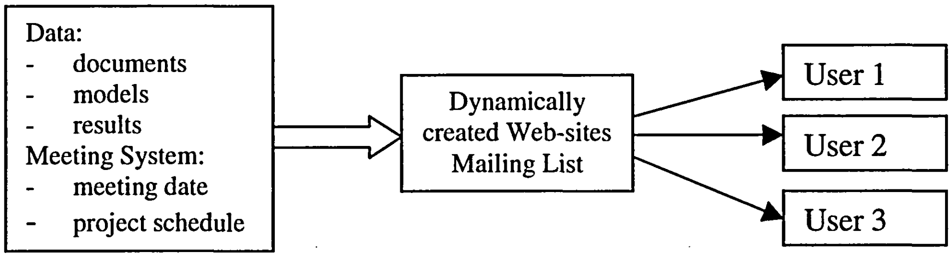

Figure 5-5 Distribution of information

Internet technologies can be effectively used to distribute models, documents, data and results between members of the simulation team and/or clients. The proposed server can be used to display documents connected with the simulation project such as objectives, proposals, meeting schedules and information, problems, etc. on dynamically created Web-sites. The site can also depend on the visiting user and his involvement in teamwork. It should allow dynamic distribution of information to every member of the simulation team. The mailing list technique, which allows redistributing mails between participants, also seems to be the proper way to meet guidelines. Figure 5-5 presents a pattern for information distribution.

The suggested solution allows keeping models at one location and distributing them after modification between involved people. It would eliminate the confusion made by a number of out of date simulation models.

5.4.2.4 Data collection

The proposed WWW-based solution allows collecting, verifying and storing data. Data can concern the simulation model, simulation project, virtual teamwork or simulation as general subject. To fulfil these requirements the SQL database server is established. The Data Base Management System orders data into the database. The user is able to put data into the database, use data in work, and search for information. Figure 5-6 shows the structure of the database.

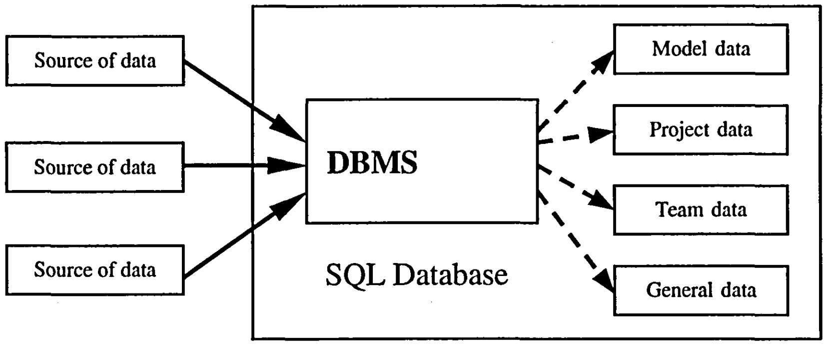

Figure 5-6 Structure of the database

5.4.2.5 Communication and Collaboration

This part of the application is the most important for the successful implementation of a virtual simulation team. Proper communication and collaboration channels should allow for establishing an efficient working environment and cooperative relations between members of the team. There are a number of conceivable solutions, which have been presented in Chapter 3. The application must have at least a few alternative tools and meet people's requirements for synchronous and asynchronous communication. Application of a particular solution ought to depend on the project's character, complexity, and budget. However, at the least the software has to allow people to communicate using e-mail, but the user should recognise the source of a particular virtual team because he may participate in the work of many teams at the same time. It has to allow organising a virtual meeting using chat technologies or an electronic video conferencing system. Moreover it is important to add an electronic meeting organisation system, which will distribute information and remind team members about electronic meetings, schedule, etc. It can be accomplished by using an electronic calendar with aforementioned mailing list, and/or by a dynamically created custom-build Web-site.

5.4.2.6 Remote execution of simulation models

The last part of the designed application is responsible for the remote execution of simulation models. It allows users to execute and interfere with the simulation calculation process via the Internet connection. The applied method should depend on the character of simulation and customer requirements. However, it also needs to offer tools to get and verify simulation results. The user should have the option what data to use – from database and/or personal (Figure 5-7)

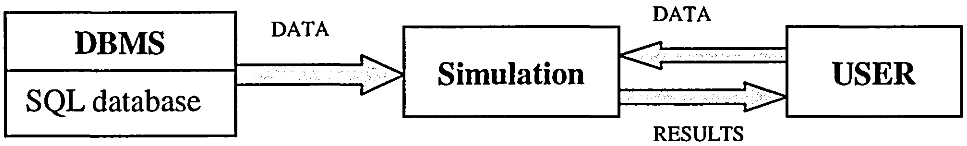

Figure 5-7 Sources of data to execute the simulation model

At present, simulation models are locally executed i.e. the end-users run models in their own machines using standard operating systems. These models are typically developed by in-house simulation specialists and/or consultants and they require regular changes. In such environments, model management and distribution become key issues. One potential solution is to enable remote execution of the simulation model so that many users can use a single simulation model. The work reported in this paper focuses on the interim findings of a research addressed to the issues involved in the remote execution of models, built using commercial simulation software.

A review of the literature identified four alternative approaches that can be utilised in this process (Whitman et al. 1998, Lorentz et al. 1997):

- Server Hosted Simulation (CGI based approach)
- Client Executed Simulation
- Hybrid Client/Server Simulation
- Client-View Simulation Output

5.4.2.6.1 Server Hosted Simulation (CGI based approach)

This allows users to access the existing simulation models, which are located in remote location(s) through a web-browser and forms-based on the Common Gateway Interface (CGI) script. Typically this allows users to tailor input data and the model execution parameters via CGI forms. A single copy of the simulation program runs on the server and passes the results of model execution to the invoking client (Figure 5-8).

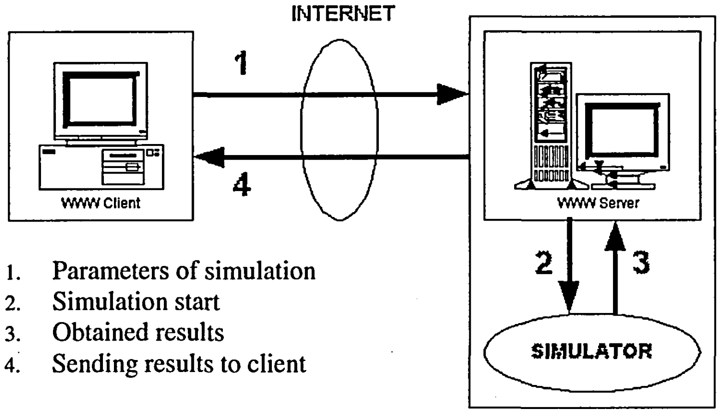

Figure 5-8 Remote simulation, animation and data transfer using CGI technology.

5.4.2.6.2 Client Executed Simulation

In this method Java programming language is used to develop a simulation code, which may be loaded as a Java applet from WWW server and executed locally on the client machine. This approach supports the incorporation of user interaction and animation into the simulation applet (Figure 5-9)

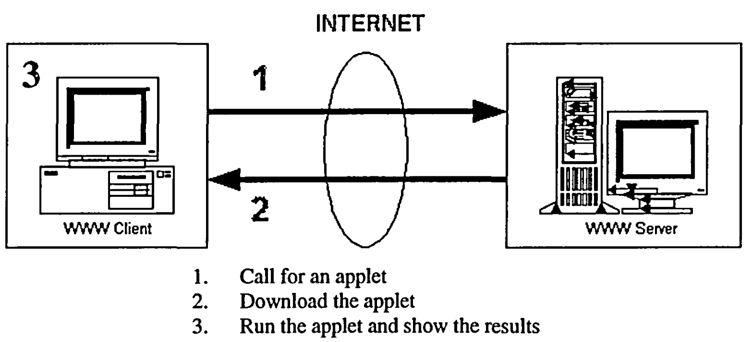

Figure 5-9 Java-based Client Executed Simulation

5.4.2.6.3 Hybrid Client/Server Simulation

This method combines the advantages of server hosted and client executed simulation. Berger and Lainer (1997) introduced this Java data server simulation and animation approach. The simulation model runs remotely on a simulation server, however the results are transferred to the client and are visualised locally. The user begins by loading some applets. After these applets have started, a connection to the Java server is built and simulation data is transmitted to the Web browser (Lorentz and Ritter 1997) (Figure 5-10).

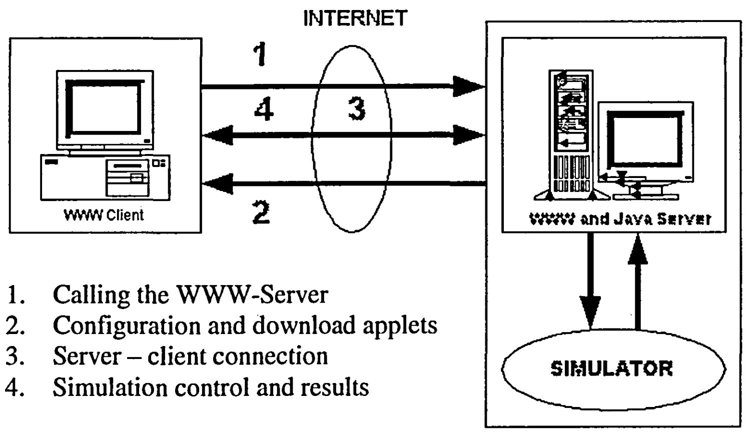

Figure 5-10 Java based methods for remote simulation and local visualisation.

5.4.2.6.4 Client-View Simulation Output

According to Whitman et al. (1998), this is type of Server Hosted Simulation where the user is limited to viewing results from a post execution file, which allows him to analyse statistical results and, usually, to view the animation file.

Considering findings it cab be concluded that the Web-based simulation utilised the CGI-based or Java-based methodology that have some inherent application as outlined in Table 5-3. However Table 5-4 presents a comparison of different approaches compiled from papers by Lorentz et al. 1997, Whitman et al. 1998, Narayanan 2000

Applications CGI scripts	Applications of Java-based modelling
Web-based access to simulation programs	Distributed modelling and simulation
Web-based access to data base	Simulation based-marketing
Web-based possibility of collecting data	
Simulation for teaching and training Web-based collaborative decision making Simulation research and methodology	

Table 5-3 Comparison of the role of CGI scripts and Java in simulation

	CGI-based approach	Client Executed Simulation	Hybrid Client/Server Simulation	Client-View Simulation Output
Can be used with existing commercial software	YES	NO	NO	YES
Applying Java programming language	Possible	YES	YES	Possible
Using alternative programming language	YES	NO	NO	YES
Single simulation model execution	YES	NO	NO	NO
Multiple model execution	NO	YES	YES	YES
Possibility of changing any parameters of simulation model	Only pre-defined	Every	Every	NO
Possibility of interrupting the execution of simulation model	NO	YES	YES	NO
Access to results of previous models execution	Possible	Possible	Possible	YES
Easy access and maintenance	YES	YES	YES	YES
Respond time	depends on software, server, and network efficiency	Quick, as model resides on client machine	depends on server and network efficiency	Quick, but depends on size of data

Table 5-4 The comparison of available technologies

5.4.3 Detail Design

It was decided that the WWW is the main platform of the system. Concluding that fact the WWW server has to be installed. The communication between user and application is maintained by HTML pages dynamically created based on the contest of a user's request or/and available data. The database is applied to collect, store and manage the virtual project team's data. The Arena programme created by Rockwell Software was chosen as the simulator, because of its availability and extensive experience gained during years of using by our research group Since the ARENA cannot support any Java related technologies the integration with Java based tools were ruled out. Hence CGI based approach was chosen to build the necessary interface.

The complete system would be assembled using three main components:

WWW Server is the Open Source Apache Server. It is responsible for displaying dynamically created HTML web pages. Using CGI scripts and PHP programming languages it allows the user to look through the resources stored in the database, displays and interacts with them.

MySQL database is used to store documents and interacts with WWW server. It gives easy-to-use maintenance methods to manage resources. The MySQL is very popular, efficient and free database package, which uses the practicality of the SQL data manipulation programming language.

Arena is the simulation software, which is applied to execute simulation models with user defined parameters. The reason for this choice was basically due to the simulation team of researchers' extensive experience gained in using this package for professional applications. Moreover Arena is a particularly easy to use high-level simulator, which also has the flexibility provided by simulation programming languages, as well as general-purpose procedural languages like the Microsoft Visual Basic Applications (VBA) programming system, FORTRAN, or C (Kelton et al. 1998).

All components are installed in one computer connected to the Internet with Windows operating system. The choice of operating system was dictated by the simulation software, which works only on the Windows platform.

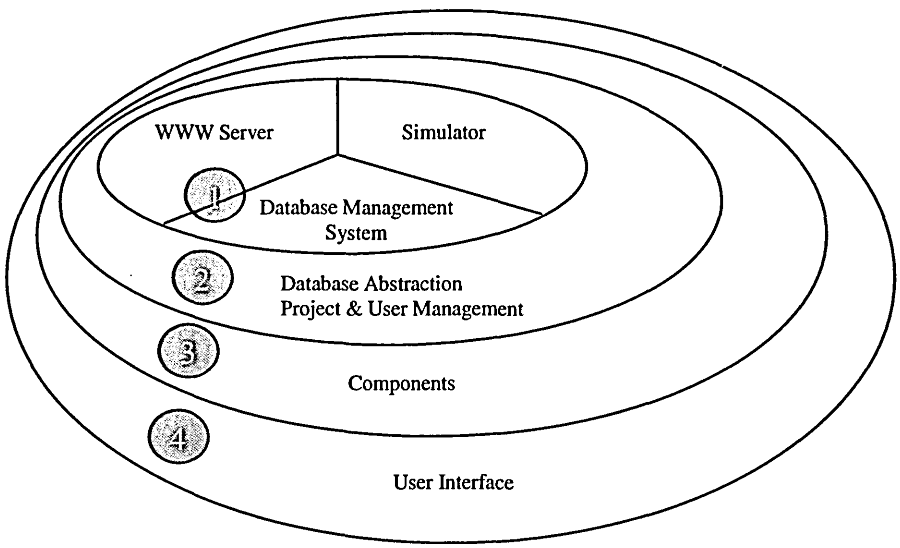

Figure 5-11 Layered application architecture

The structure of the application can be described as a layered architecture that is illustrated in Figure 5-11. That approach helps to achieve the necessary modularity, which facilitates an easy integration of the variety tools used during the development.

The Layer 1 consists of the Web Server, database with database management system (DBMS) and Simulator (Arena Software). The applied server-side solution allows the dynamic generating of Web pages to interact with the user. The Common Gateway Interface (CGI), Java Servlets and PHP Hypertext Protocol (PHP) are applied to realize server-created dynamic pages.

The Layer 2 implements the basic user and project management to facilitate project-based/virtual team cooperation. This layer defines rules for interconnection between individual components, generates the content of the Web-pages, exchanging data between simulation team members and/or system, and provides the means to display the output of all components in one common user interface. This segment also operates the user authorization process.

The functionality of the Layer 2 is exploded by Layer 3, which represents particular components of the system, such as project data, model execution, view results, collect data, workgroup, project scheduling, etc.

The last Layer 4 is the user interface that is based on the Web-browser and dynamically generating Web-pages, which are used to maintain dialog between users and the application.

Applied architecture allows, among other things, the execution of pre-built simulation models over the Web-browser. A client can evaluate different scenarios by comparing results from their execution, which are stored in the on line database. The user interface is based on HTML forms with additional functionality provided by PHP programming language and Common Gateway Interface (CGI).

Other parts of the application are responsible for collecting data and managing the simulation team's data. The link between team members is established by synchronous (chat) and asynchronous (e-mail, discussion list).

5.4.3.1 System Functionality

The system is based on WWW server, mySQL database and Arena simulator. It allows for lively day-routine interaction between members of the simulation team. The participants, in the first step, have to login to the server via the web page.

The successful verification of user login and password gives access to the web-site of the simulation virtual project (Figure 5-12). The main - initial page includes the main navigation menu and the updated information about next scheduled project's event.

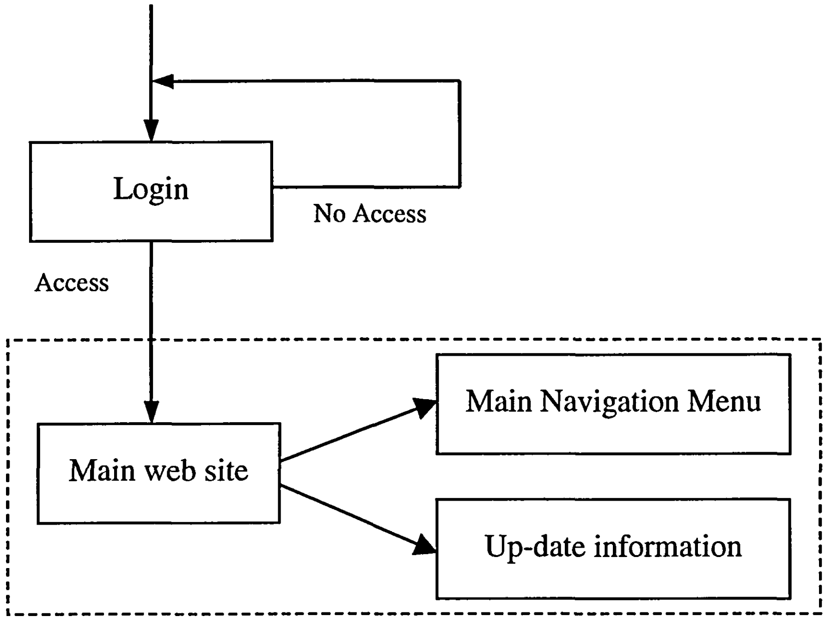

Figure 5-12 Diagram of the process of user login

Concluding the literature review presented in chapter 1 and the discussion from chapter 4, where the methodology for virtual simulation team were proposed, the project of main window and navigation panel is proposed. After consultation with simulation practitioners that the main navigation panel that allows user to move between particular options, has to include following ingredients:

- Project documentation
- Project and meetings schedule
- Model execution
- Review simulation results
- Virtual meeting
- Team members' feedback
- Asynchronous communication - Email and Whiteboard
- Synchronous communication - Chat
- Collect data
- Help

In the following subchapters the process of developing all components is presented in details.

5.5 Development

This phase brings in the practical work to create the new system/application into being the product. Based on the project specification and design the application was developed. The development process was divided into small tasks, which were solved individually. The code for the number of web-pages that pages interact with the database and display the contents of the database query were created. The developed application allows for dynamic and lively interaction between users and server. Then the final product was tested thoroughly during experiments.

5.5.1 Developing the application

In the first step, the development was focused on achieving the working prototype with minimal graphics elements. In order to minimise the cost of application software, components, codes freely available on the Internet were used. Based on the requirements gathered in Table 5-1 the focus was also put on establishing an efficient communication and collaborative environment, and, at the same time, to obtain simplicity of use and maintenance.

The main components of application:

- WWW Apache server (www.apache.org) - open source WWW server introduced in Chapter 5.4.3; Apache version 1.3.20 was installed;
- mySQL (www.mysql.org) - open source database presented in Chapter 5.4.3; mySQL version 3.23.53 was installed;
- Arena Simulation Software - introduce in Chapter 5.4.3; Arena version 5.0 was installed;
- PHP (www.php.net) - it is a widely-used general-purpose scripting language that is especially suited for Web development and can be embedded into HTML increasing its functionality and flexibility; PHP released number 4.2.3 was installed;
- PERL (www.activestate.com) - it is general-purpose programming language, which among other things can be used to create CGI scripts; AcivePerl version 5.6.1 was installed.

Additional software:

- Tomcat (http://jakarta.apache.org) - it is the servlet container that is used in the official reference implementation for the Java Servlet and JavaServer Pages technologies; Tomcat 4.1 was installed as a requirement of used a chat programme jChatBox;

- jChatBox (http://www.javazoom.net) - it is freely available, easy customised, and high performance synchronised Servlets/JSP chat software; installed version 2.5;
- HyperCam (http://www.hypercam.com) - it is freely distributed powerful video capture software that records AVI movies directly from your monitor, for software presentations, software training, demos, and tutorials; installed version 1.70.02

5.5.1.1 Project documentation

The list of available documents is displayed based on the data gathered in the project database. The user can look on-line through documents, download them, search through using basic search rules, such as date, topic, etc. All materials correlated to the simulation project, and participants having access to all historical date are collected in the database. Figure 5-13 shows an example of that output.

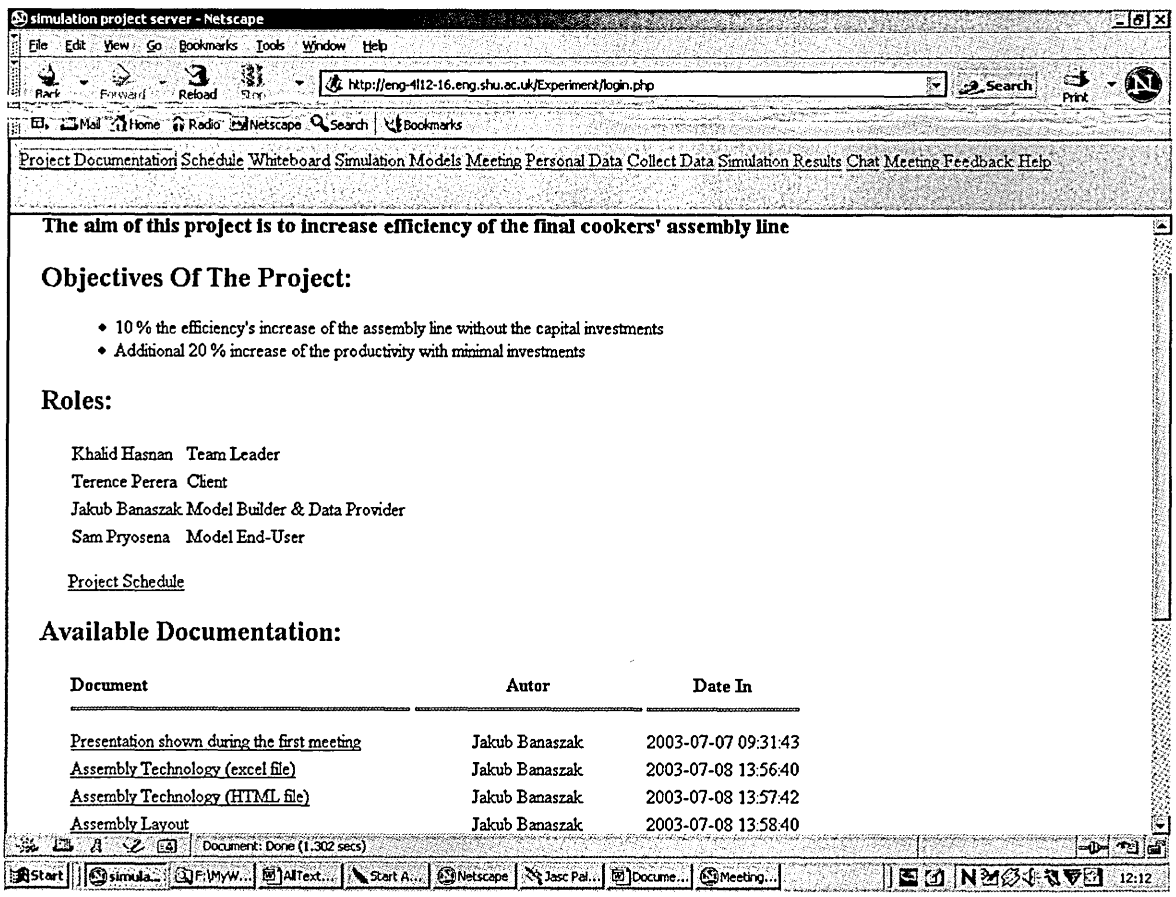

Figure 5-13 The page with documentation of the simulation project

5.5.1.2 Project and meetings schedule

This component based on the context of data in the database displays information about the project schedule, as well as the future meeting schedule. The events are displayed in date order, and the user can choose between project and meeting schedules. Figure 5-14 presents an example of the screenshot.

The project schedule consists of date, project stage, and name of the responsible team member or members. The meeting schedule is composed of date and a topic of a meeting, and hyperlink to the proposed meeting agenda. Different colours are used to distinguish the future events from past ones.

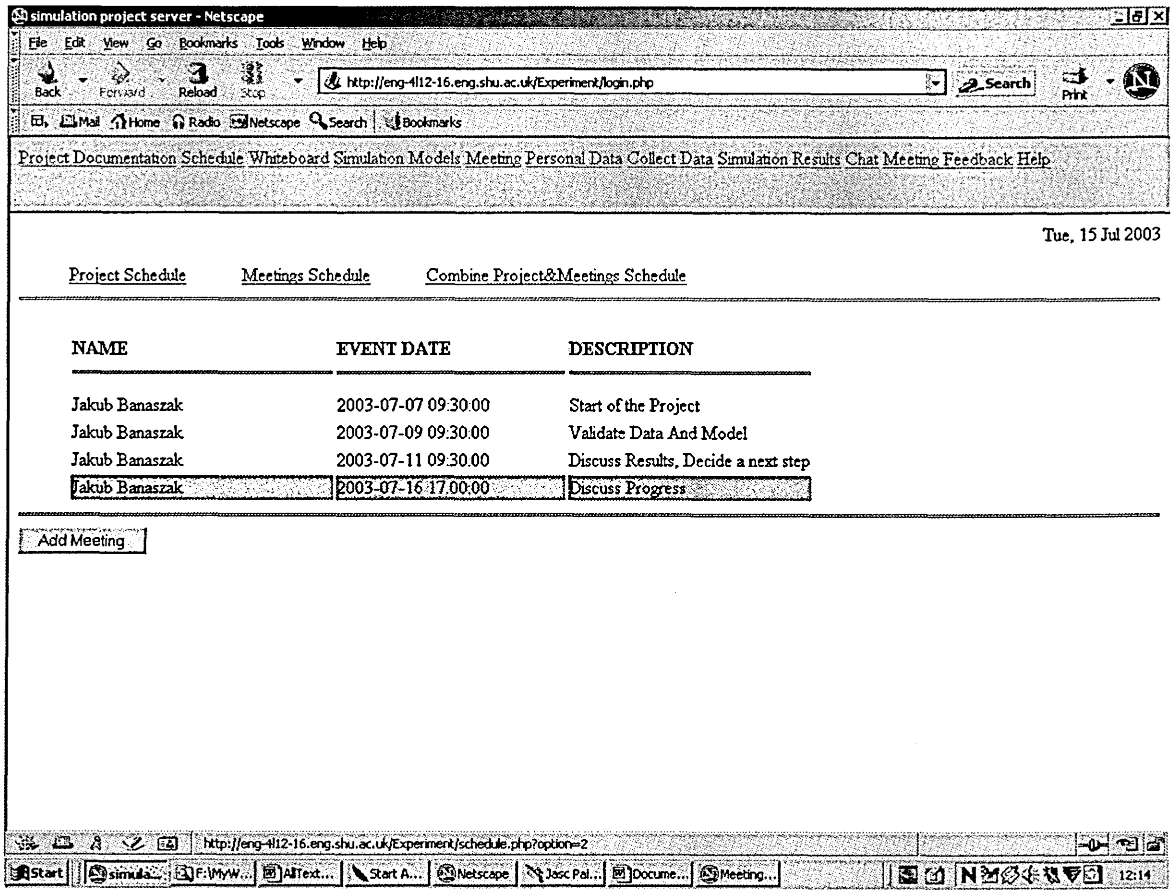

Figure 5-14 Meetings schedule

5.5.1.3 Model execution

This section allows the execution of simulation models. The user can choose one from the list of available models, put his data, execute the scenario and view results (Figure 5-15).

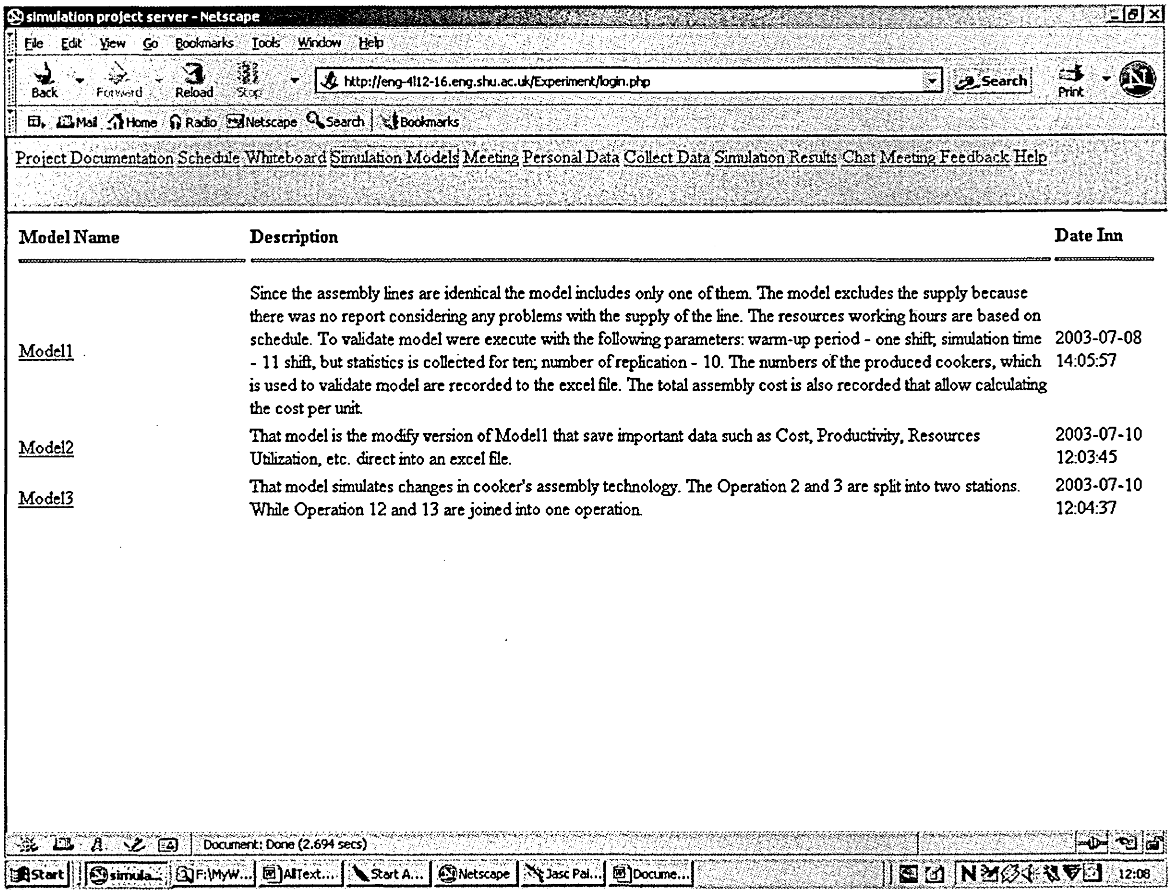

Figure 5-15 The models' list developed during a experiment

5.5.1.4 Review simulation results

This component displays the list of results from previous model executions, which allows for comparison of the results from different scenarios (Figure 5-16).

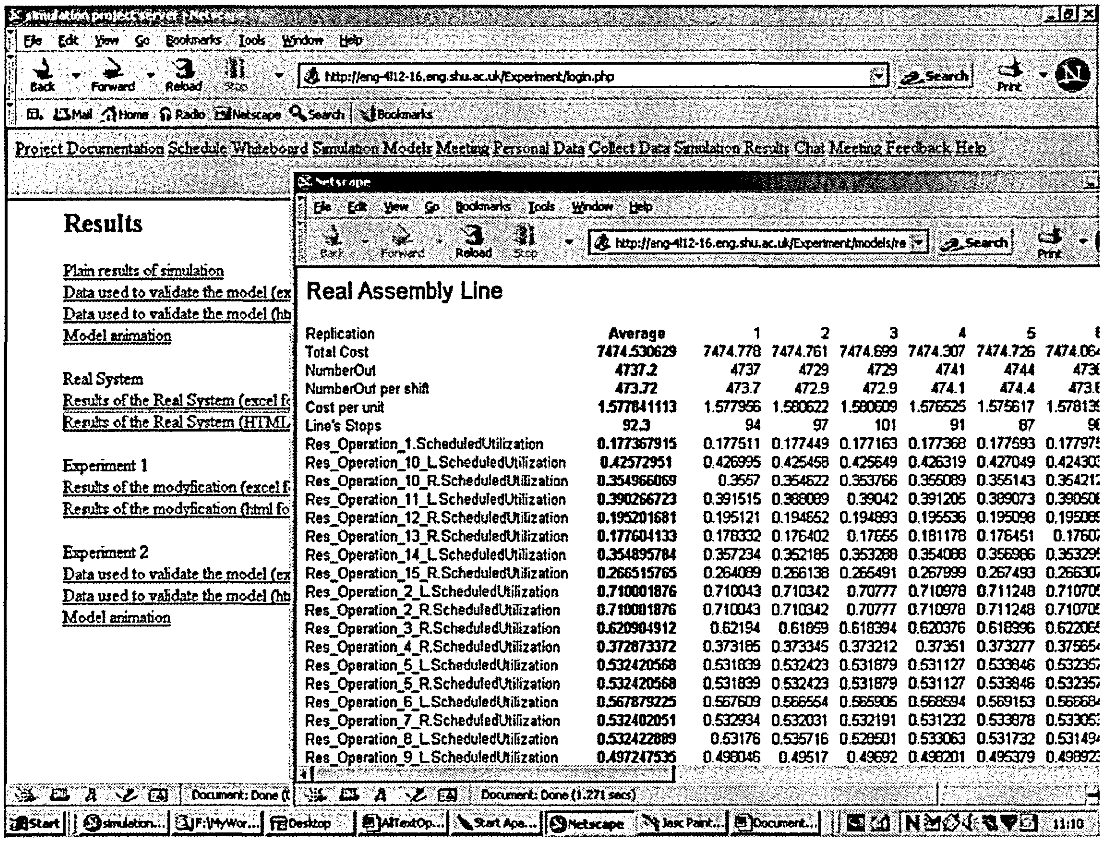

Figure 5-16 The review of simulation results

5.5.1.5 Virtual meeting

That section includes data appropriate to the virtual meeting such as meeting agenda, meeting output, historical data from previous meetings, users' feedback, etc (Figure 5-17).

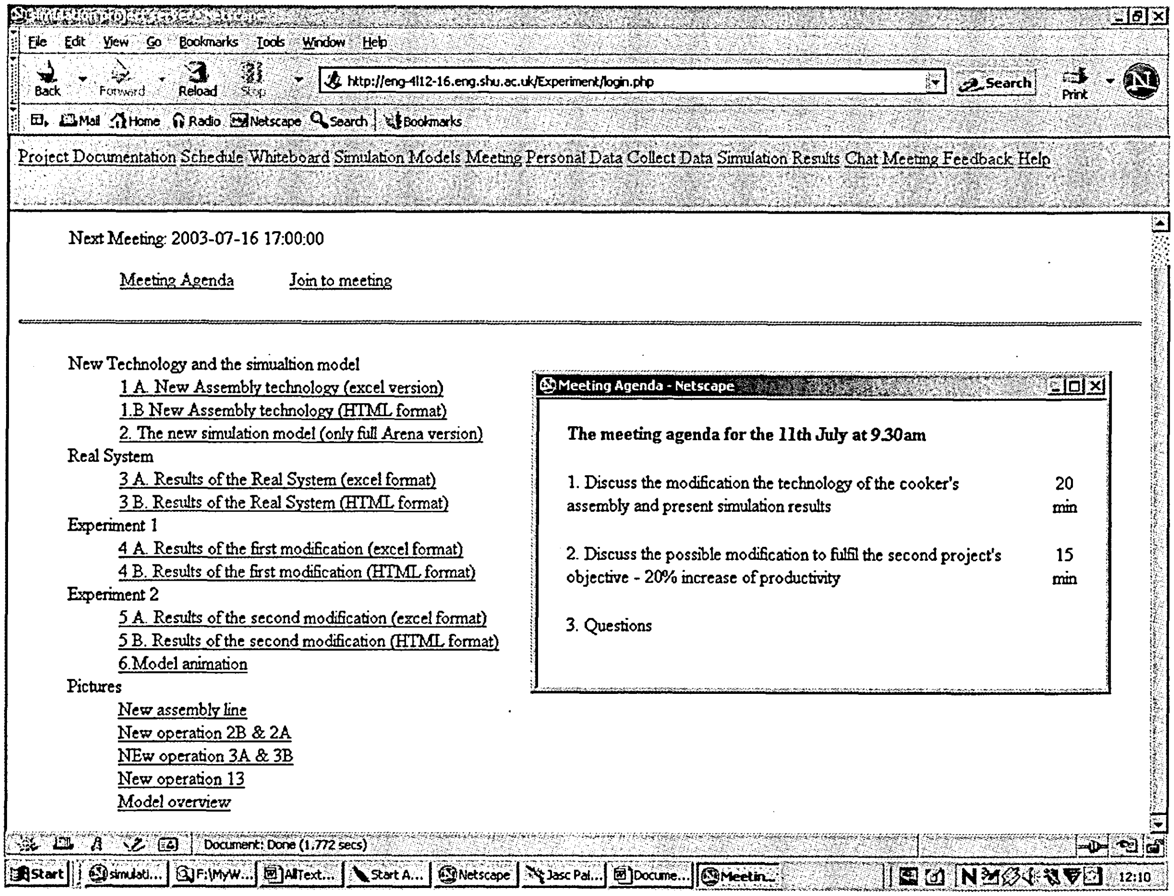

Figure 5-17 The meeting's page with link to meeting agenda, documents, and chat

5.5.1.6 Team members' feedback

In this component users can express their opinion about virtual meetings, progress of the project, conflicts, etc. The data would help the team facilitator and team leader to improve the performance of the team (Figure 5-18).

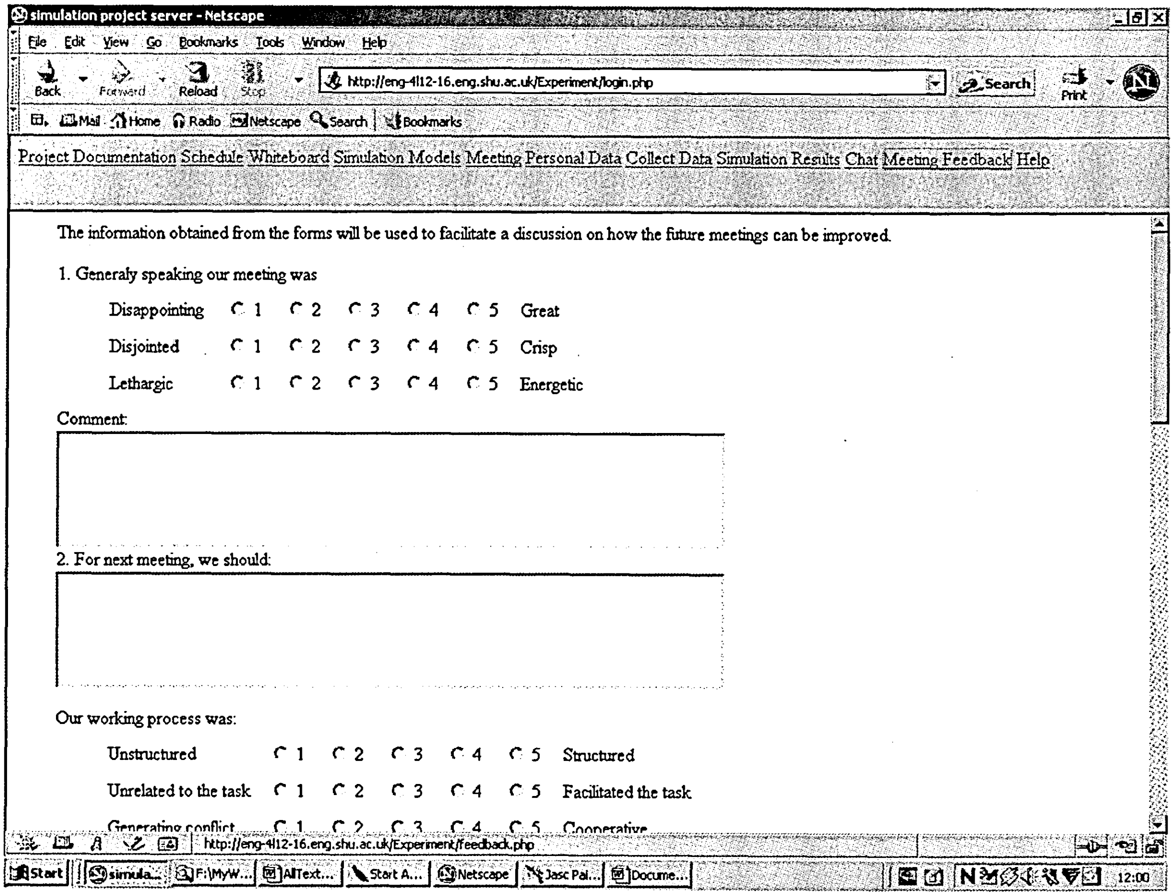

Figure 5-18 The feedback form

5.5.1.7 Asynchronous communication

Email and Whiteboard

The whiteboard section allows participants to discuss the problems, express their opinion, look for help, etc. Email is used as the main medium to distribute and exchange information.

5.5.1.8 Synchronous communication

The synchronous discussion during the meeting is maintained by the chat room. The discussion is recorded and accessible for future reference. The chat has also hyperlinks to documents discussed during a virtual meeting (Figure 5-19).

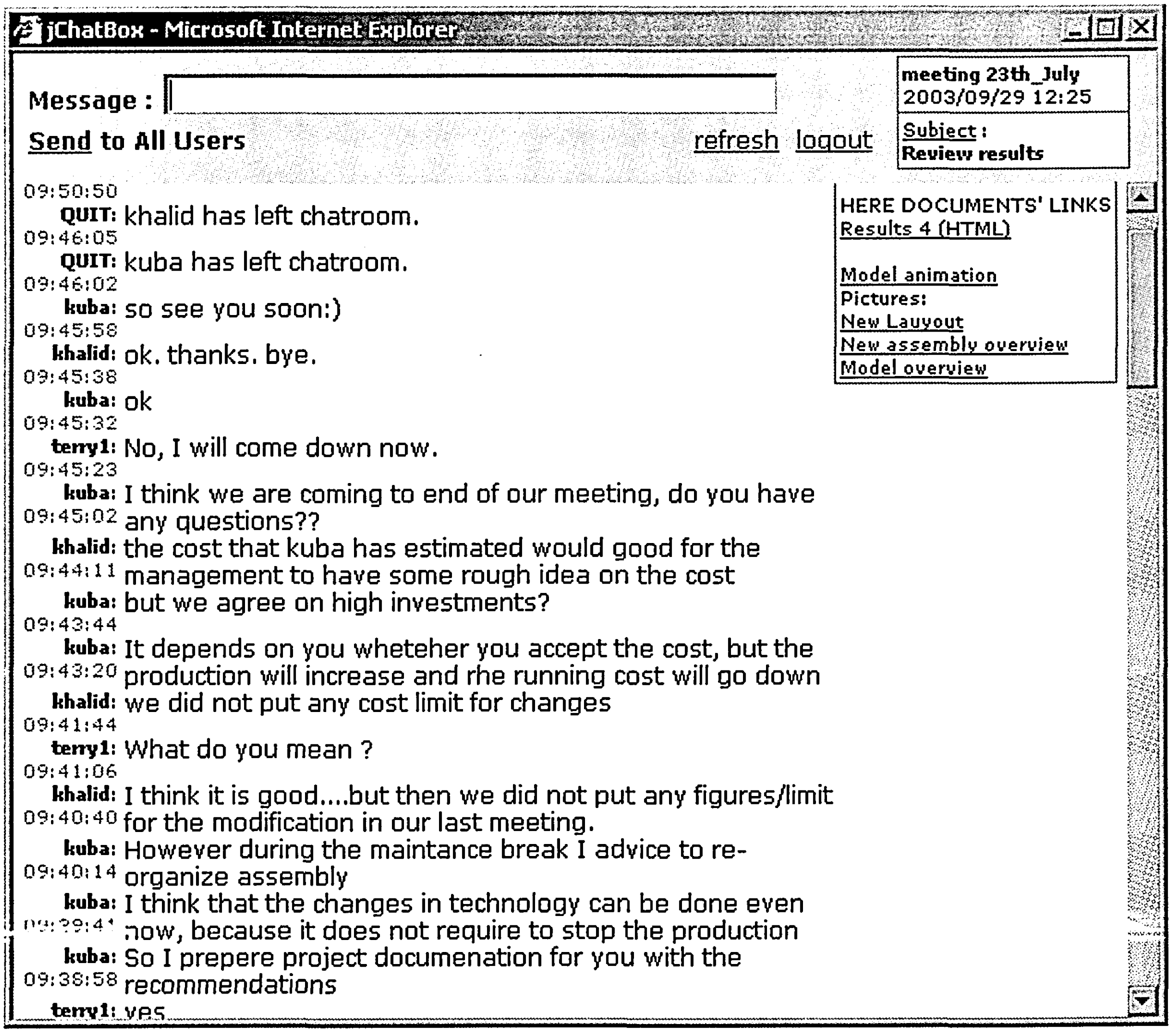

Figure 5-19 Chat window with hyperlinks to relevant documents

5.5.1.9 Collect data

This section allows collecting and reviewing data considering the requirements of the simulation models development.

5.5.1.10 Help

In this component the users can look for help about the system and its particular components and features. The help also includes knowledge about processing and working in a virtual team (Figure 5-20).

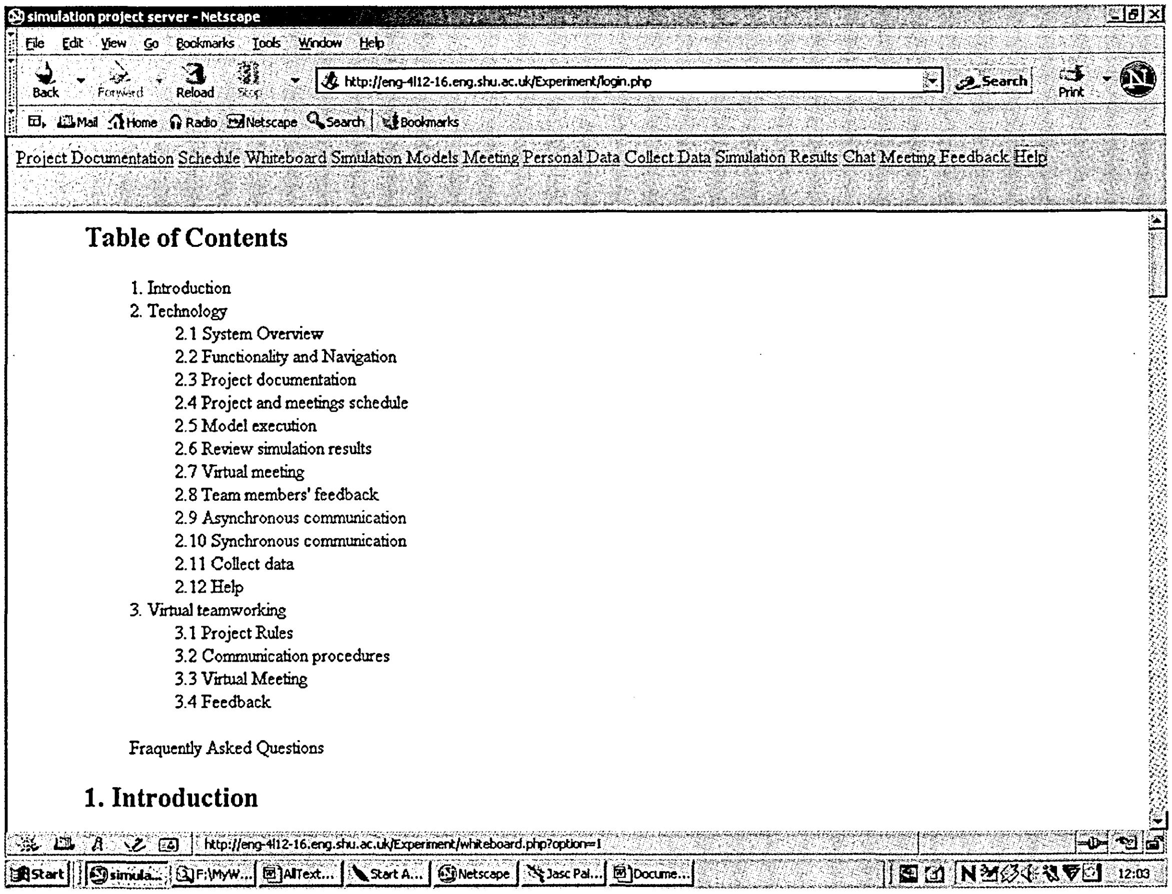

Figure 5-20 The on-line help's content

Having the working application the testing phase could start. After it the additional graphical features were added and the application was presented to the group of researchers, who were asked to take part in the testing of it. The experiment was set up to get information from users, check the efficiency and usefulness of the application.

5.5.2 Testing the application

A group of people were gathered to form the simulation team. The problem was formulated, the simulation team set-up, and roles were divided between people. The training session allowed participants to familiarize themselves with application, the idea of the experiment and start up the test project.

The test project and outcome of testing and validation project are discussed in Chapter 6.

5.6 Implementation

The key point in implementation is to persuade users to switch to the new system. To minimise the problems with implementation the whole operation ought to be planned carefully. People, who will use the system must be trained, data files converted and all implementation activities coordinated and scheduled.

The data gathered during the experiment (Chapter 6) was used to test the application. The users' opinions were collected, analysed, and modifications made. That process customises the application according to users' requirements, and allows for detection of errors.

The final version of the application was introduced to people involved in the testing process.

6 Empirical validation of the methodology and technology for virtual teamworking in a simulation project

This chapter describes the experiment that was carried out to evaluate the proposed methodology for creating a virtual simulation team (Chapter 4) and examine the developed application (Chapter 5). During the research the virtual simulation team was formed to solve a problem using the simulation tools and communication technology. The face-to-face contacts were limited only to the experiment start meeting. The project's progress was monitored and participants' opinions were collected to examine the proposed approach.

6.1 The experimental virtual simulation team

The experimental virtual simulation team was formed following the methodology described in Chapter 4. The creation process was based on the framework proposed in Chapter 4.5 (Figure 6-1). The emphasis was put on factors such as people, simulation project, virtual meeting and support technology. Selected people from the research group took part in an introduction meeting. That meeting was divided into two parts. During the first one the participants were familiarized with the idea of the experiment and virtual teamworking. While the second part was used to form the virtual simulation team and describe the problem, which needed to be solved.

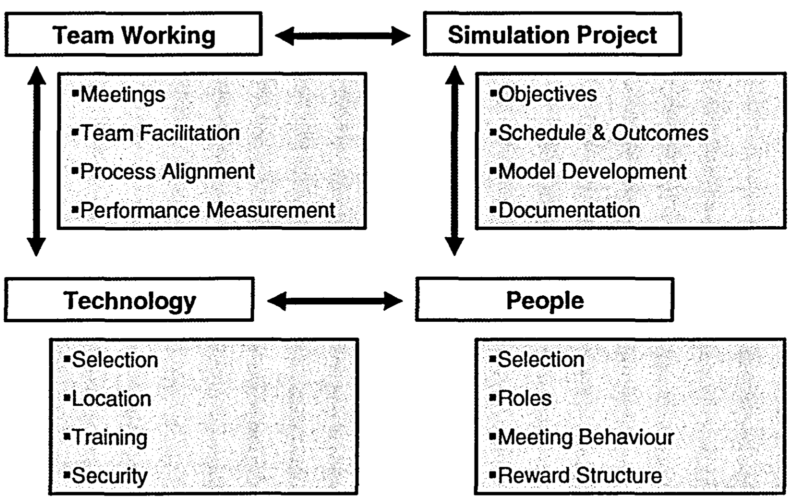

Figure 6-1 The framework for the virtual simulation teamworking

After the first face-to-face meeting all cooperation efforts were carried out in a virtual environment based on the developed web-application with synchronous and asynchronous communications. That approach relates to the proposed scheme of virtual simulation project in Chapter 4.6.2 (Figure 4-4) that recommended the first meeting to be traditional to introduce people and the problem, build trust, make the training session, collect and sign appropriate documents, visit (if possible) a investigate site or process, etc.

However, the collaboration work is then carried out using the web application and the virtual meetings. The participants can follow the project's progress through available documents and discussion generated during the team meetings.

6.2 The objectives of the experiment

The aim of the experiment was to make a simulation study based on the virtual teamworking. The experiment's objectives were:

- validate the proposed methodology for forming the virtual simulation team
- valuate the developed application for supporting the virtual teamworking;

6.3 Simulation Project

The simulation team was challenged to solve a real problem using the simulation techniques.

A company that produces cookers plans to increase its production. However, in order to do that it has to increase the efficiency of its existing final assembly department, which already works three shifts while other departments only one or two shifts. Figure 6-2 shows the layout of the assembly department with two final assembly lines. The lines are the production bottlenecks and the assembly department must find a method to increase their productivity.

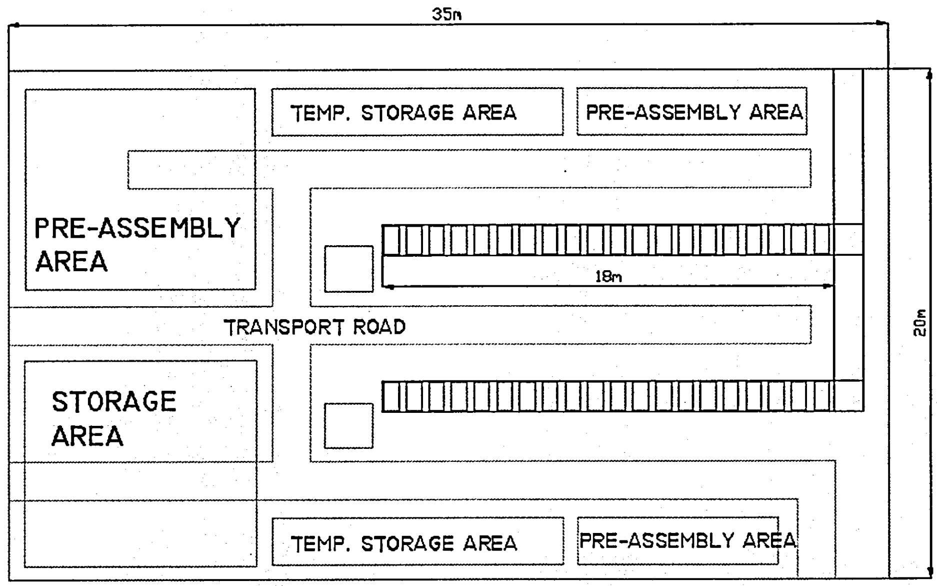

Figure 6-2 The layout of the final assembly hall

6.4 First meeting - creation of the virtual simulation team

6.4.1 The structure of the first meeting

The first meeting, which was face-to-face, took place on 7th of July 2003 and consisted of:

1. Explaining the idea of the experiment
2. Introducing virtual simulation team concept
3. Presenting the problems
4. Organizing the virtual simulation team
   - Define the roles
   - Set up the objectives of the simulation project
   - Create schedule and expected outcomes of the project
   - Meeting schedule and structure
   - Introduction of the support application
   - Virtual meetings
   - Cooperative behaviour during the work & meetings
   - Meeting facilitation
   - Performance measurement
   - Reward

6.4.2 The outcomes of the first meeting

The experiment's aim was presented to the people. The training session introduced the participants to the methodology, application and communication protocols. Then the problem was presented and the objectives of the simulation project were agreed (Table 6-1). The simulation team members were assigned their roles and responsibilities (Table 6-2). Because the people involved in the experiment were busy with their own research most of the time consuming work was assigned to the research author. The schedule of the project (Table 6-3) and meetings (Table 6-4) were also created.

Number	Objectives of the simulation project
1	Increase the efficiency of the assembly lines by 10 % without capital investments
2	Increase the efficiency of the assembly lines by 20 % (high investments)

Table 6-1 The Objectives of the simulation project

Name	**Role**
Student 1	Team Leader
Student 2	Client
Student 3	Model Builder, Data Collector, and Team Facilitator
Student 4	Model End-User

Table 6-2 The people's roles assigned during the experiment

Project's schedule	
Data	**Event**
2003-07-07	Start of the Project
2003-07-09	Data Collecting & First Model Building
2003-07-11	Experiments & Results Analysis
2003-07-26	Documentation & Finishing the Project

Table 6-3 Schedule of the project

Table 6-4 Schedule of the meetings

Meetings' schedule	
Data	**Event**
2003-07-07 09:30:00	First meeting - Start of the project (traditional one)
2003-07-09 09:30:00	Validate Collected Data And Simulation Model
2003-07-11 09:30:00	Discuss line modifications and results; Decide a next step
2003-07-16 17:00:00	Discuss the progress of the project;
2003-07-26 14:00:00	Final meeting - Finish the project

The training session allowed participants to familiarise themselves with application, virtual teamworking concept, and applied procedures. Strong emphasis was put on the future virtual meeting with requirements to be prepared for the meeting, by downloading and reading discussed documents, working with chat, switching between windows, and responding to questions, e-mails, or other events.

The project's participants were told to leave feedback after every virtual meeting, which would be used to assess the project's progress, and validate the methodology and the application.

6.5 Virtual meetings and outputs

The collaboration process was carried out through a number of virtual meetings, which were made using computer network and developed web application. Participants had the access to the project's web site where the updated project's documentation was published. The chat technology was used to generate discussion, opinions and ideas. The virtual meetings had agendas that were distributed to the team members before meetings with relevant documents.

The structure of the meeting followed agenda, and discussion was guided by team facilitator and team leader. The participants were asked to leave feedback after the meeting to monitor the project's progress and their opinions. That allows supervision of the teamworking and reacting fast to observed obstacles. Table 6-5 presents the summary of the virtual meetings. The feedback left by participants is presented in Table 6-6.

6.6 Validation of the proposed framework

The experiment successfully validated the proposed methodology, because the simulation project finished productively by achieving its objectives, and the virtual collaboration were balanced and fruitful. The introduced framework (Section 4.5) effectively covers the virtual simulation structure and focuses the four main points: people, team working process, communication technology and specification of simulation project.

The first face-to-face meeting was used as a project's kick-off, when team players meet each other for the first time to build a good relationship and trust, start the project, and learn a technology and working protocols. While the virtual meetings were used to discussed the progress of the project and generate ideas. Regular meetings with guided discussion by team facilitator allowed keeping the team focused on the task.

The experiment also validated the developed application. Detected chat error was fixed and users' opinions were canvassed for improvements.

The built web-based application allowed the effective execution of virtual simulation teamworking. However, users expressed the desire to have in the future more interactive tools such as whiteboard, and voice- or videoconference facilities.

Virtual Meeting	Event Date	Agenda	Outcome	Users' Opinions
1	2003-07-09	• Validate the collected data - 10 min • Present the model - 5 min • Validate the model - 10 min • Design experiment - 10 min • Questions	• Collected data was validated • Model of real system was positively validated • The chat error detected	• It was reported that there was need for more direct reference to the document and/or piece of data during the conversation • The users had to be prepared for the meeting and download documents before the actual event
2	2003-07-18	• Discuss the modification to the technology of the cooker's assembly and present simulation results- 20 min • Discuss the possible modification to fulfil the second project's objective - 20% increase of productivity - 15 min • Questions	• The changes in assembly technology were accepted • The results were validated • The new line's cycle time 46 seconds that gives increase productivity by 15.45% • The first project objective was achieved • Proposition to modify assembly layout generated	• Presentation was better - direct information reference; and the documents and windows better managed • The discussion was better guided • No problem with technology
3	2003-07-23	• Review the assembly modifications - 20 min • Discuss the results - 15 min • Questions	• Validate results for the new assembly layout • Obtained increase in efficiency by 50% fulfil the second project's objective	• Good and balanced discussion • Users express needs for more interactive presentation tools

Table 6-5 The summary of the virtual meetings.

Virtual meeting	Disappointing ÷ Great	Disjointed ÷ Crisp	Lethargic÷ Energetic	Unstructured ÷ Structured	Unrelated ÷ Facilitated task	Generative conflicts ÷ Cooperative	Balance of participation	Sharing of opinions	Success in resolving conflict	Success in taking decision
	1 ÷ 5	1 ÷ 5	1 ÷ 5	1 ÷ 5	1 ÷ 5	1 ÷ 5	%	%	%	%
1	3.3	3.6	3.5	4	3.9	4	65	69	70	75
2	4	4.5	4.5	4.5	5	5	72.5	70	72.5	72.5
3	4	4.5	4.5	4.9	5	4.5	78	75	70	75

Table 6-6 The Participants' feedback

The experiment also brought to light the participants' lack of experience in virtual teamworking. They had to learn through their own mistakes during the collaboration process, especially concerning the issues of the virtual communication and collaboration. That resulted on a request for a more sophisticated training session in communication at the beginning of the project, and strict collaboration procedures.
The conclusions of experiment were as follows:

- Proposed methodology allowed the establishment of an efficient virtual simulation team
- People needed extensive training to become virtual team members
- The developed Web application was successfully tested, verified and improvements made

The research showed that the success of the virtual simulation team depended on four main aspects that were reflected in the proposed framework:

- Team working that included documented guidelines, procedures, their alignment to the virtual environment, and management of virtual meetings
- Simulation project requirements, objectives, schedules and documentation
- People involved in collaboration possessing abilities to utilize technology to effectively communicate, share knowledge and transfer ideas
- Technology that linked all parties involved in the project in order to create an efficient and user-friendly platform for team member interaction.

6.6.1 Team Working

Virtual team working is possible relaying advances in electronic communication technology. According to Duarte and Snyder (2001), the correct technology is very important, however the appropriate selection and users' training is the main key success in the implementation of virtual collaboration. Lurey and Raisinghani (2001) research showed the utilization of particular technologies, such as email, group telephone conference, shared database, etc. by virtual team and their effectiveness in virtual collaboration processes. They also found that their respondents complained about the lack of face-to-face interaction, and the trouble of determining which tools were most appropriate to use, based on situational factors like the content of the message as well as the intended audience.

Taking onto account the experiment results and findings in the literature the team working factors are vital to success of a virtual simulation project.

6.6.2 Technology

Taylor (2000) investigated the application of communication technologies in a simulation project life-cycle and in simulation consultant work. He also pointed out the potential project cost savings of groupware applications by reducing no-added-value activities such as travelling. But he also identified the lack of knowledge about the subject and mental resistance to the new way of working. In his next paper (Taylor 2001) proposed the NetMeeting as the support application and evaluated the importance and usefulness of different available communication tools in simulation projects, such as text chat, file transfer, videoconference, audio conference, whiteboard and application sharing.
However, Johnson et al. (2001) supported the author's statement about the importance of team members training. Also how to maintain effective communication within the constraints of a virtual environment, such as communication problems, lack of project visibility and problems in keeping touch with people. In conclusion technology provides an environment by which we are able t implement proposed framework and it is vital to include technology factors in proposed framework

6.6.3 People

Suchan and Hayzak (2001) pointed out that the supporting technology had to capture, organize and store their knowledge electronically, making it easier for them and others to access and share.
The Duarte and Snyder (2001) focused on, the human factor in virtual team working. The other part of proposed framework includes concerns with appropriate personnel selection, based on their knowledge and ability to work in a virtual team as it is very important to the output of project. Commitment and team accomplishments must be emphasized by a reward system (Suchan and Hayzak 2001), which is also presented in the framework. The results show that it is essential to include people factors in the proposed framework.

6.6.4 Simulation

The team and as well as the simulation project must have a defined purpose and objectives, which guide and focus the team. The alignment of team collaboration processes to the virtual environment allows the establishment of structural and social patterns appropriate to simulation project objectives. To successful implementation of the virtual simulation team methodology it is vital to include the simulation project factors in the proposed framework.

The three stages approach presented in Chapter 4 proved to be the proper approach to carry out a simulation project in virtual teamworking. The face-to-face kick-off meeting at the beginning of the experiment developed the trust, and commitment, and was used to train team members in technology, collaboration rules and etiquette. Then in the next stage, the virtual simulation teamworking maintained by the team leader and team facilitator was supported by effective utilization of communication technology. The findings of that project are supported by the work of Bal and Gaundry (1999) that pointed out that a virtual team requires some formalized communication protocols and procedures to keep the team focused and on track and to avoid conflicts and misunderstandings.

The developed framework and methodology for transforming the simulation team into a virtual one proved to be valid because it reflected and consolidated the reports and findings of many authors from different industries and backgrounds. The accumulated knowledge and the author's experience enabled the effective adjusting of the virtual team concept into a simulation project life-cycle. The proposed framework and methodologies took into consideration all the important factors and helped to effectively move the team working into the virtual environment.

7 Simulation of the different team working approaches in simulation project life-cycle - analytical validation of the virtual simulation team methodology.

This part of the study involved the discrete simulation to analyse and compare the different scenarios of team working in the simulation project life-cycle. Three models were built that represented the three different models of team working. Models were used to compare the cost and actual time needed to complete the project depending on the different cooperation approaches. The author expected that virtual teamworking should reduce the cost of the simulation teamworking. However, the scale of the expected savings had to be known in order to gain support and collaboration from management people for the proposed concept of the virtual simulation team.

7.1 Problem definitions and objectives sets up

The objectives of this study are to introduce the virtual teamworking into the simulation project life-cycle. To show the advantages of the proposed methodology, in terms of project's budget and schedule, the author had to make a comparison of the project's cost, time and data flow in different cooperation models, which represented traditional face-to-face and virtual teamworking.

The objectives of the study were to compare the three different cooperation scenarios:

1. Traditional based on the face-to-face meeting with the data exchange only during the meetings (Figure 7-1a).
2. Traditional based on the face-to-face meeting with the constant data flow between team participants (Figure 7-1b).
3. Virtual meetings with the constant data flow between team participants (Figure 7-1b).

The difference between (1)(2) Traditional team and (3) Virtual Team is based on applying advanced communication technology to set up meetings over the space. That approach eliminates the need for time consuming and costly travelling to the meetings by participants (Figure 7-2). It also allows establishing regular, more frequent meetings without exceeding the project's budget.

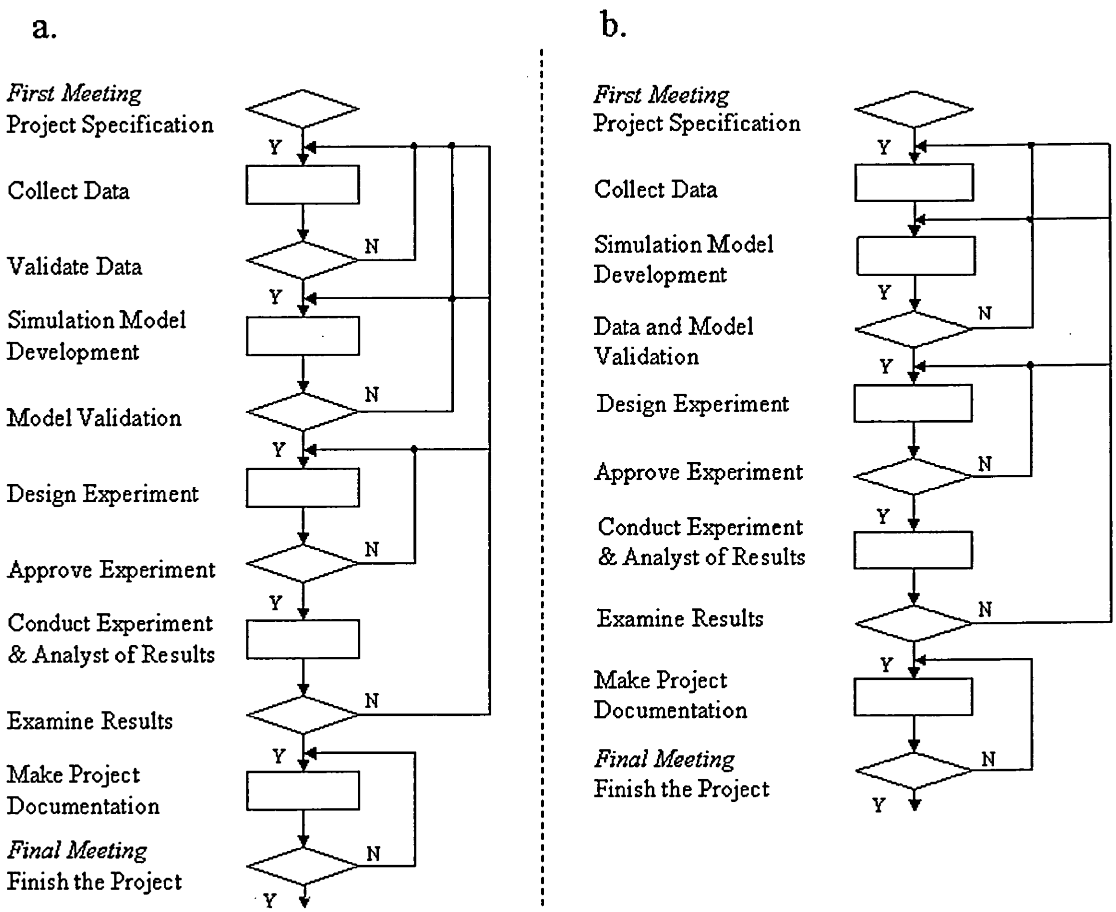

Figure 7-1. Diagram of the team working in the simulation project: a) face-to-face meeting with the data exchange only during the meetings; b) meeting with the constant data flow between team participants.

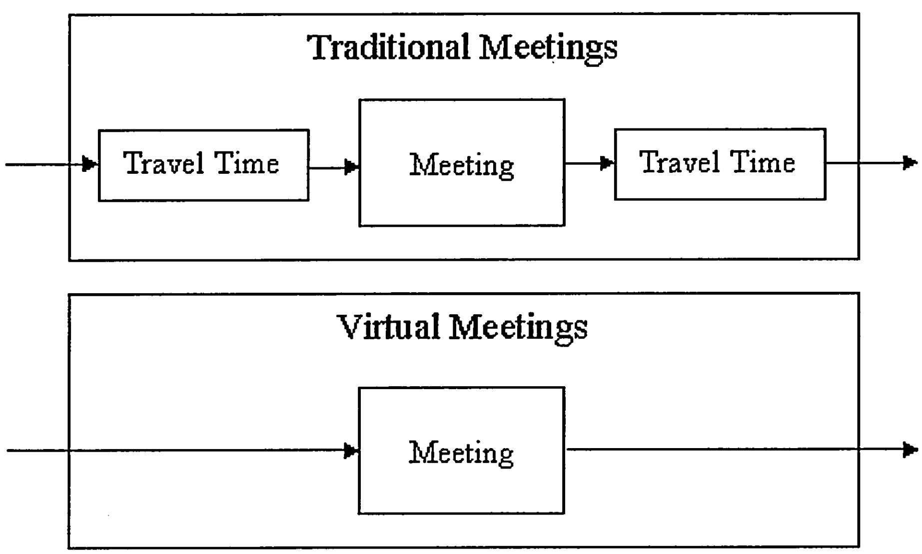

Figure 7-2. Modelled difference between traditional and virtual meetings.

7.2 Simulation models

To represent the different cooperation scenarios described in the previous chapter the three simulation models were developed. The models were created in Arena 7.0 simulation software, which was also used to conduct experiments.

Functionality

The information flow diagrams (Figure 7-1) were employed to develop models for each alternative team working approach. While building the process stress was put on obtaining user-friendly models. In that case the numbers of variables were applied, which values the user can input using the customised form. Moreover, the results are saved automatically to the spreadsheet for further statistical analysis.

The data describes the project stages

There is a lack of data describing the total time of the simulation project in proportion to the time of the particular stages of the project life-cycle. This happens because the duration of a simulation project depends on the problems to which simulation is applied, their complexity, data availability, etc. To overcome that shortage the author decided to apply the following methods. User input into the models approximated total time of the simulation project life-cycle, and in percentage of total time the time for particular stages of the simulation project. Results of survey made by Yapa (2003) were applied to specify the time of the stages of a project (Table 7-1)

	Average time of project's stage [%]
Problem/Objective definition	18.8
Model building and testing	40.7
Experimentation	25.3
Project completion and Implementation	20.8

Table 7-1 Average time of different stages of simulation project life-cycle

However, to minimise the insufficiency of input data the experiments were carried out for a different total time and different time distribution between phases of the simulation project. Figure 7-3 shows the input data form with example data.

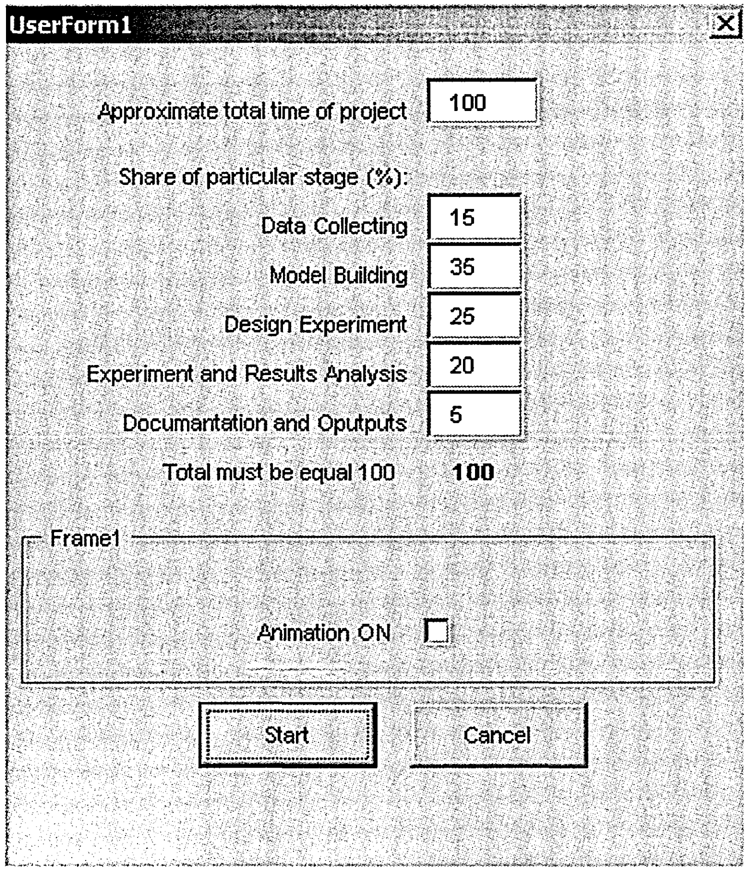

Figure 7-3 The execution start menu

However, the simulation project is described as an iterative process with possibility of returning to the previous step in case of any problems, needs or inaccurate data (Chapter 1 - Simulation project life-cycle) the timing of the stage was additionally divided. When the stage is carried out for the first time it is 0.8 of time for that stage, and value 0.3 if the stage is repeated.

The meetings data

Based on experience of the System and Enterprise Group at Sheffield Hallam University the meetings times were assigned as normal distribution with different value of mean μ and standard deviation σ depends on stage. Obviously the first meeting takes longer, as well as discussion results than other meetings during simulation projects. Table 7-2 presents assigned value for the meetings.

Traditional Meetings: $t_{left} \geq t_{travel} + t_{meeting}$

Virtual Meetings: $t_{left} \geq t_{meeting}$ Equation 1

t_{left} - Time left till the end of working hours

$t_{meeting}$ - Meeting time

t_{travel} - Travelling time

Simulation team meetings	Time data	
	μ [hour: minutes]	σ [hour: minutes]
Formulate the problems	2:30	0:30
Review collected data	1:00	0:20
Review simulation model	1:00	0:20
Review experiment	1:00	0:20
Review results	2:30	0:30
Review documentation	1:20	0.30

Table 7-2 Assign meetings time

The resource schedule

Based on Robinson (1994) the models simulate the following project participants: team leader, model builder, client, data collector, model end-user. However, there is an additional resource - team facilitator; in a virtual team to facilitate meetings and technology. The resources work five days a week, 8 hours a day. Whenever they are free the process can start. The exception to that rule is the start of the meeting when the work time left must be longer or equal to the approximate time of meetings (Equation). Also the meetings can take place only on Monday, Wednesday or Friday. Moreover the travelling time is also taken into consideration in the traditional face-to-face meetings.

Cost

To calculate the cost of the project the following value of the resources' cost and travel cost were assigned Table 7-3.

Cost component	Cost (£/hour)
Team Leader	30
Client	30
Modeller	20
Model End-User	15
Data Collector	15
Team Facilitator	20
Travel Cost (for all together)	50

Table 7-3 Review the cost of the resources

7.3 Design Experiment

Simulation models are applied to evaluate the difference in project total time and total cost of the project for the three scenarios of the team working described in Chapter 7.1. The influence of three parameters is examined:

1. Approximate time of the project,
2. Time distribution of the project's stages
3. Time of the travelling

According to the plan there were 3 planned experiments, which are described in the details below.

Experiment 1

The first experiment's aim was to investigate how the distributions of time between the stages of the simulation project influence, if at all, the total cost and total time of the project. However, there is a lack of validated and unequivocal data concerning the time consumed by any particular stage of the project. This is caused by the individualism of each simulation project, which brings different requirements and challenges.

Considering that problem the experiment was designed to avoid the effects of the inaccurate input data, which was mentioned before. For the same constraints, such as resource schedule, travel time, etc. each model was calculated for the different time distribution between the project's stages. In total it was planned to examine five different scenario-time distributions, which are presented in Table 7-4. The scenarios represent about ± 5% of data collected by Yapa (2003). Those tests were made only for the models of traditional meetings - Model 1 & Model 2 (Chapter 7.1)

	1	**2**	**3**	**4**	**5**
Data Collecting	20%	10%	20%	20%	20%
Model Building	40%	40%	40%	30%	50%
Design Experiment	10%	15%	5%	20%	10%
Conduct Experiment & Analyse Results	15%	15%	20%	20%	15%
Documentation & Implementation	15%	20%	15%	10%	5%

Table 7-4 The examined time distribution

Experiment 2

During the second experiment an influence of the approximate total project time was investigated. In real life the total time of the simulation project depends on many factors, such as the complexity of models, availability of data, etc; and can vary from a day to months or even years.

Considering that, it was decided to make an experiment for four different approximate project's time: 10, 20, 50, 100 hours of active work on the project. That approach allows looking for any pattern and trends, how those changes influence cost and real time of the project.

Experiment 3

The aim of the third experiment was to investigate the impact of the resources' travel time to and from the meeting on the project total time and cost. Traditional face-to-face meetings force people to bear the expenses of travelling, which increases the cost of the project without generating additional value to the project.

The experiment was carried out for three normal distributed travelling times that are presented in Table 7-5.

	1	2	3
μ	1 hr	2 hr	4 hr
σ	0.1 hr	0.1 hr	0.2 hr

Table 7-5 The parameters of the traveling time's normal distribution

7.4 Conducting Experiment & Analysis of the Results

The experiments were carried out in Arena Software. Each scenario was calculated for 200 replications, which gives sufficient data to conduct statistical analysis of the results. The results from Arena were exported to the Excel spreadsheet where additional analyses were conducted.

The examination focuses on two main factors including the total cost of the project and total time needed to finish the simulation project. Also, the factors such as the cost of the meetings, and their influence on total project cost.

Results of Experiment 1

In this experiment the influence of the time distribution between project's stages (Table 7-4) on the total time and cost of the simulation study was investigated. The simulations were conducted for two models representing two collaboration scenarios presented in Figure 7-1.

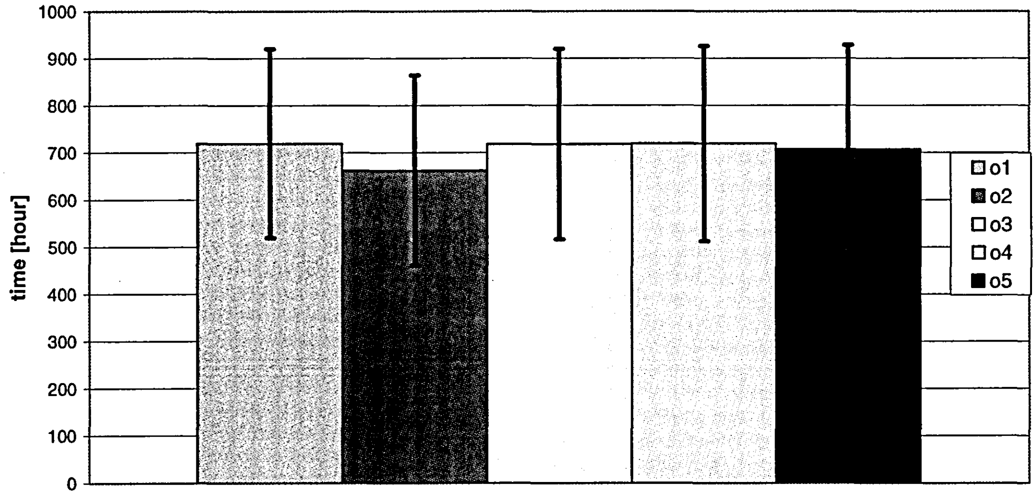

Figure 7-4 Total Project Time for different project's stages time distribution in the Team 1

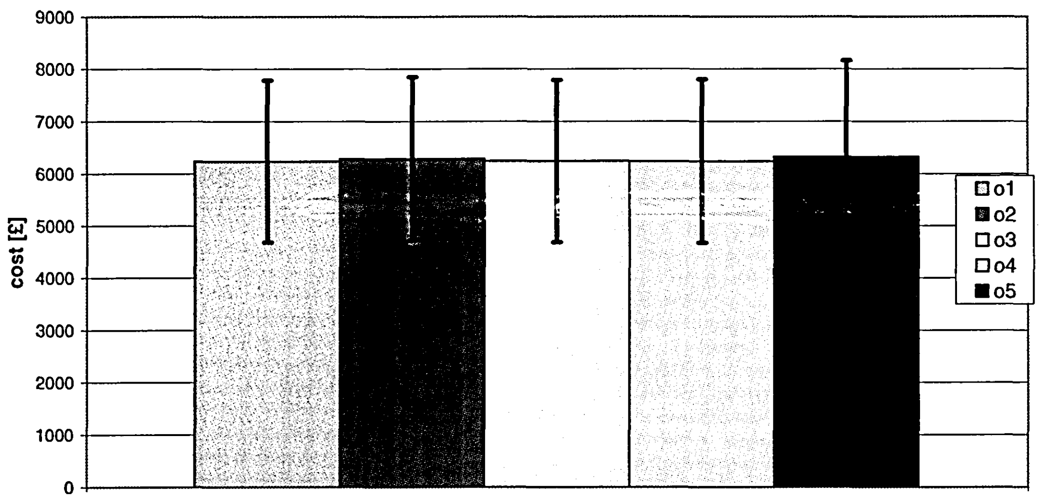

Figure 7-5 Total Project Cost for different project's stages time distribution in the Team 1

Figure 7-4 shows the distribution of the total time while Figure 7-5 shows the cost in the traditional team (Team1). Figure 7-6 and Figure 7-7 present the results for the traditional team with parallel process (Team 2).

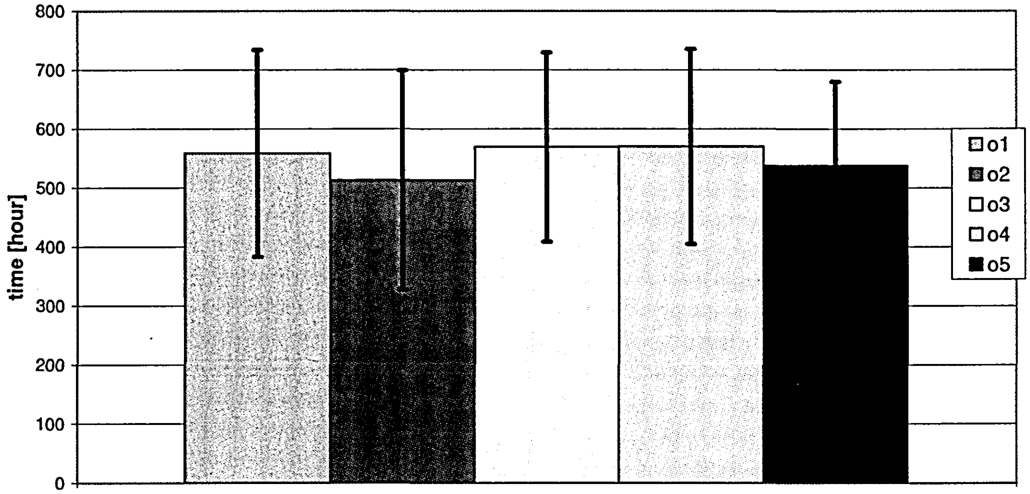

Figure 7-6 Total Project Time for different project's stages time distribution in the Team 2

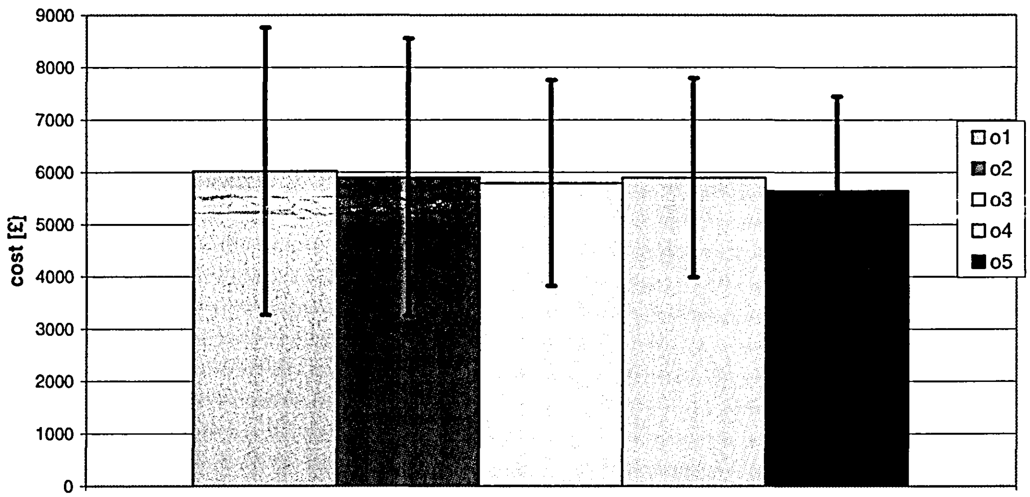

Figure 7-7 Total Project Cost for different project's stages time distribution in the Team 2

The analysis of the results shows marginal, in the range of error, differences between scenarios in case of cost and time. The outcomes confirm reality, because independent of the methods and scenarios, the project must go through all stages, include all processes, and insignificant differences are made by differences in labour cost (Figure 7-8). However, Figure 7-9 shows the advantage of the second teamwork approach in case of the total project time, which in Team 2 is about 20% less than in the Team 1.

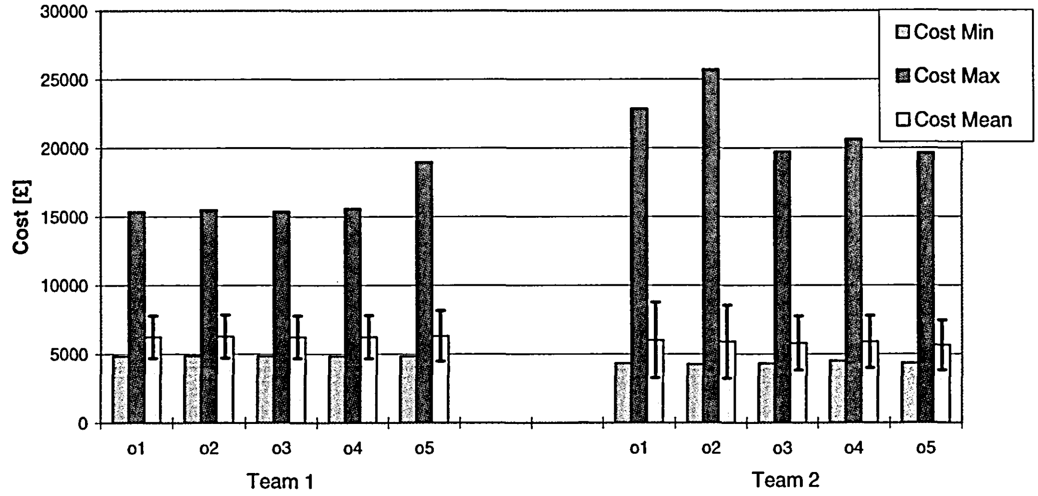

Figure 7-8 Comparison of the Total Project Cost between scenarios

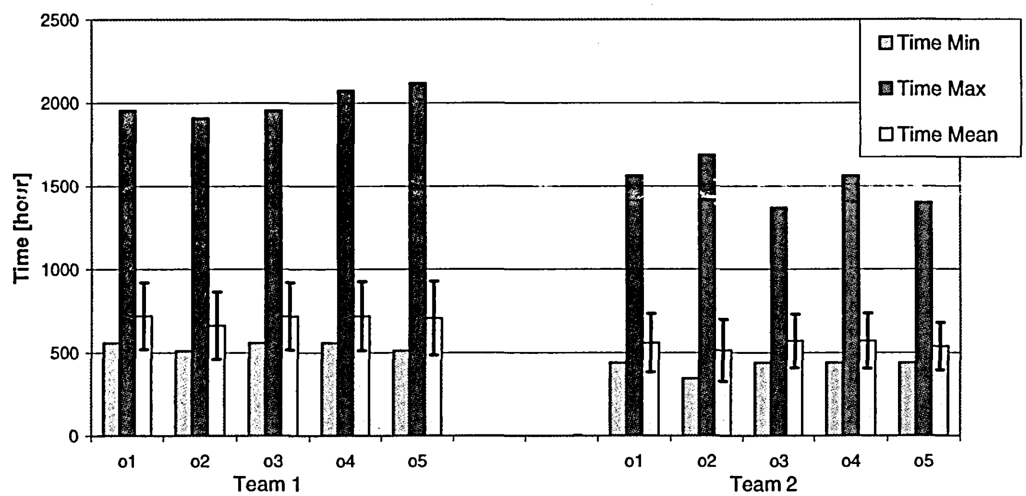

Figure 7-9 Comparison of the Total Project Time between scenarios

Results of Experiment 2 and Experiment 3

Concerning the results from Experiment 1 the first distribution time of the project stages was applied during the following experiments. To obtain a larger spectrum the two experiments were coupled and for each project time (10, 20, 50, 100) the calculations were made for each travelling time (Table 7-5).

Figure 7-10 shows a distribution of the Project Total Time depending on the travel time and second parameter - the approximate process time, while Figure 7-11 presents the Project Total Cost for Team 1. Meanwhile Figure 7-12 and Figure 7-13 show results for Team 2 with the same constraints. The results prove implication of the travel time on the project time and cost. The increase in the journey time causes a significant increase in the project completion time, as well as the project cost.

However, in next step these results were weighed against the results for the Team 3, which is the model of the virtual simulation team, and are presented in the following Figures: Figure 7-14, Figure 7-15, Figure 7-16, Figure 7-17, Figure 7-18, Figure 7-19, Figure 7-20, and Figure 7-21.

To compare the results three factors were introduced:

1. Cost Factor [%] that relates the particular project cost to the cost of the same project made in the virtual environment.
2. Time Factor [%] that relates the particular project time to the time of the same project made in the virtual environment.
3. Knowledge Cost [£/meeting number] that presents the cost of a knowledge gathering by team members. The participants' knowledge is related to the number of meetings and it is developed during the project through the meetings (Chapter **Error! Reference source not found.**).

The calculated factors for each process time are shown in tables: Table 7-6, Table 7-7, Table 7-8, and Table 7-9.

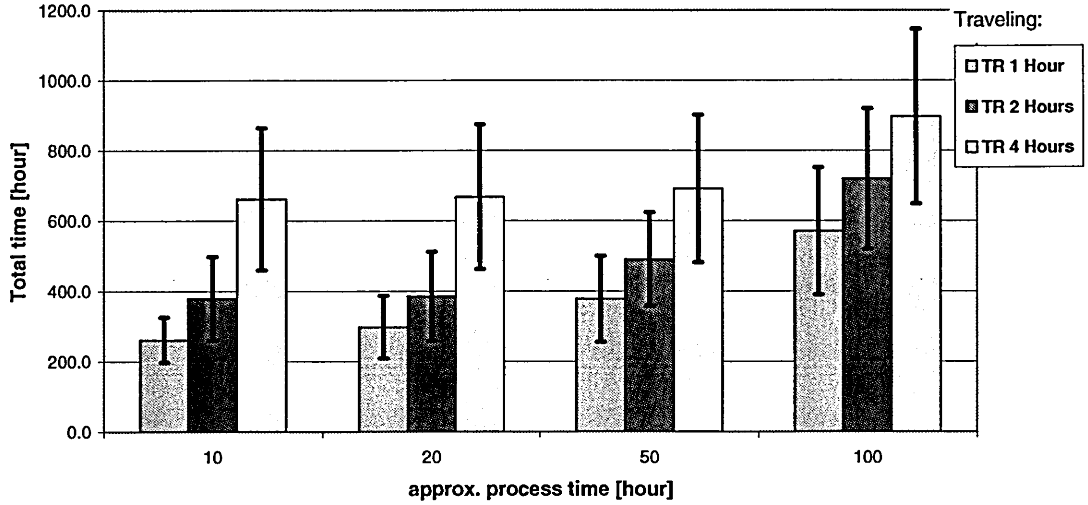

Figure 7-10 Project Total Time depends on travel time and approximate process time for the Team 1

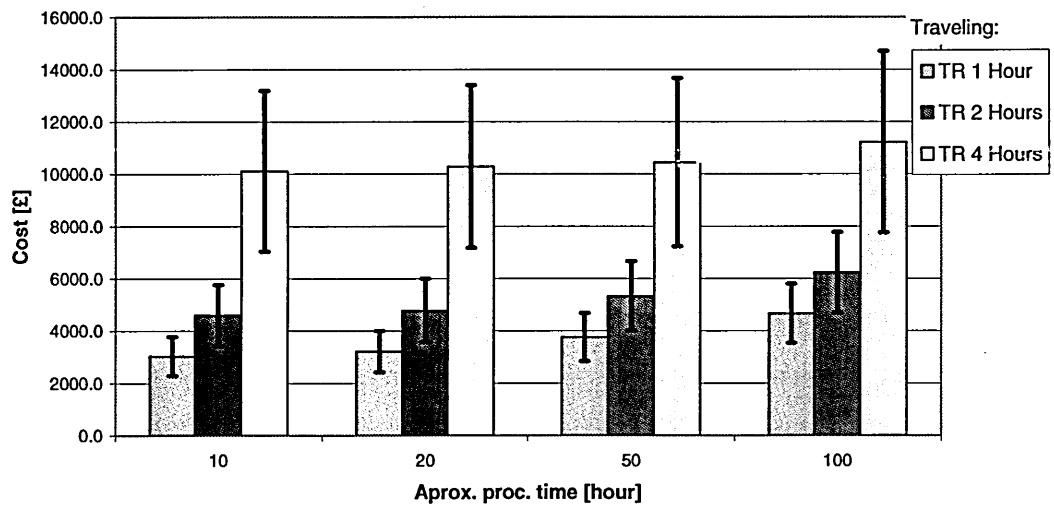

Figure 7-11 The Total Cost of the project depends on travel time and approximate process time for the Team 1

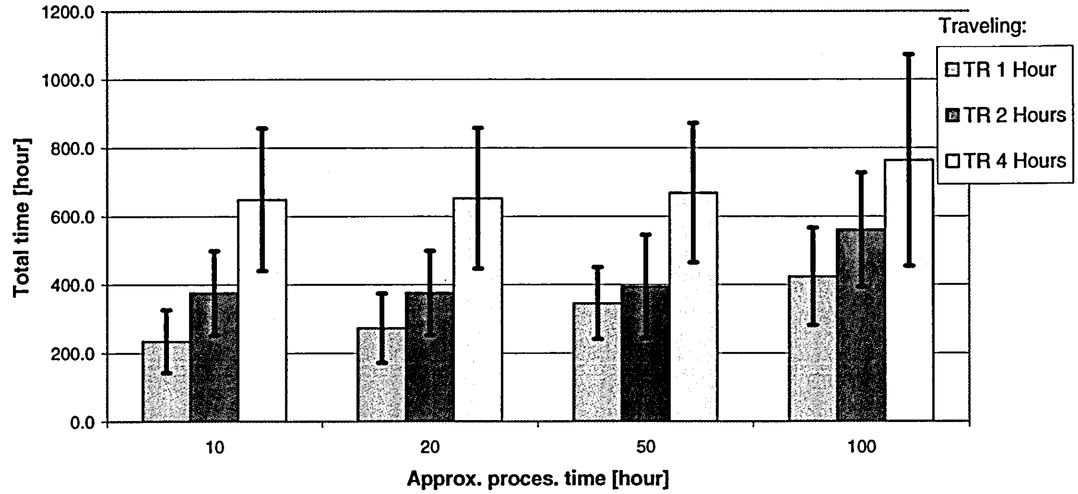

Figure 7-12 Project Total Time depends on travel time and approximate process time for the Team 2

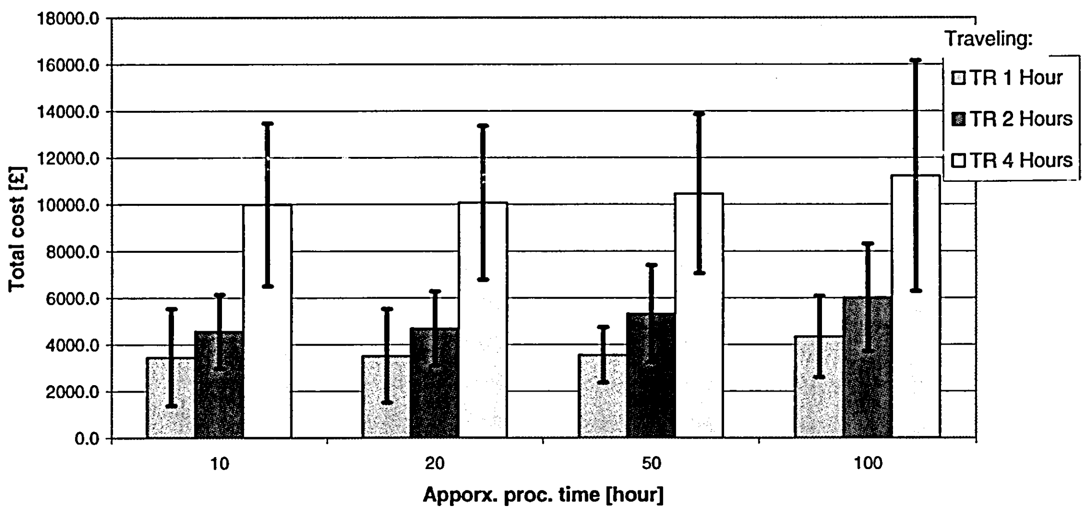

Figure 7-13 The Total Cost of the project depends on travel time and approximate process time for the Team 2

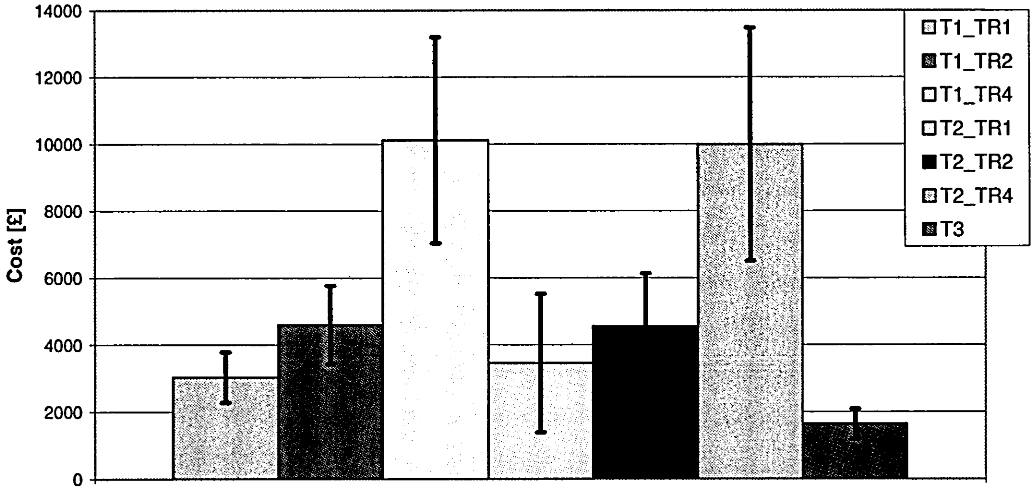

Figure 7-14 Evaluation of the Total Project Cost for the approximate process time 10

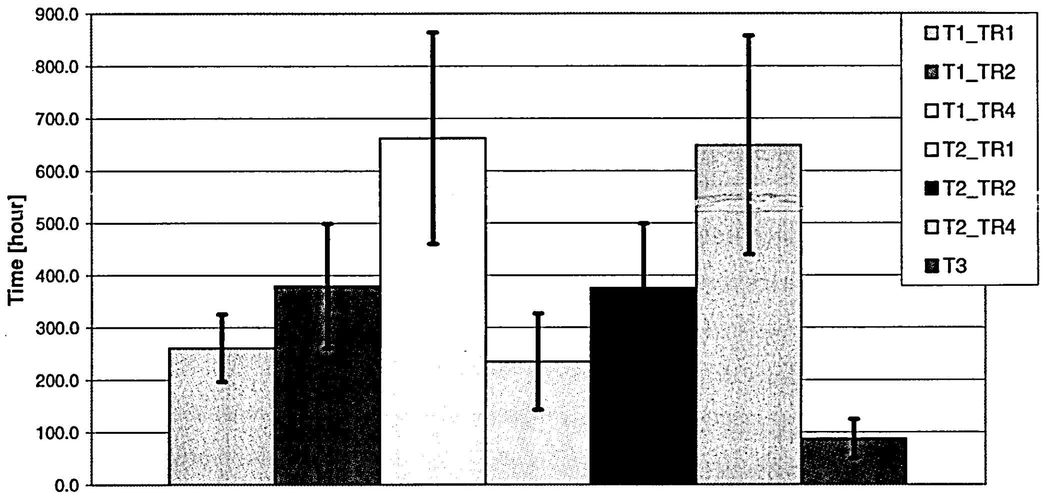

Figure 7-15 Evaluation of the Total Project Time for the approximate process time 10

	Team 1			Team 2			Team 3
Travel Time [hour]	**1**	**2**	**4**	**1**	**2**	**4**	**0**
Cost Factor [%]	185	281	617	211	277	609	100
Time Factor [%]	299	434	757	269	430	742	100
Knowledge cost [£/meetings]	379	575	1264	432	569	1249	205

Table 7-6 The calculated factors for process time 10

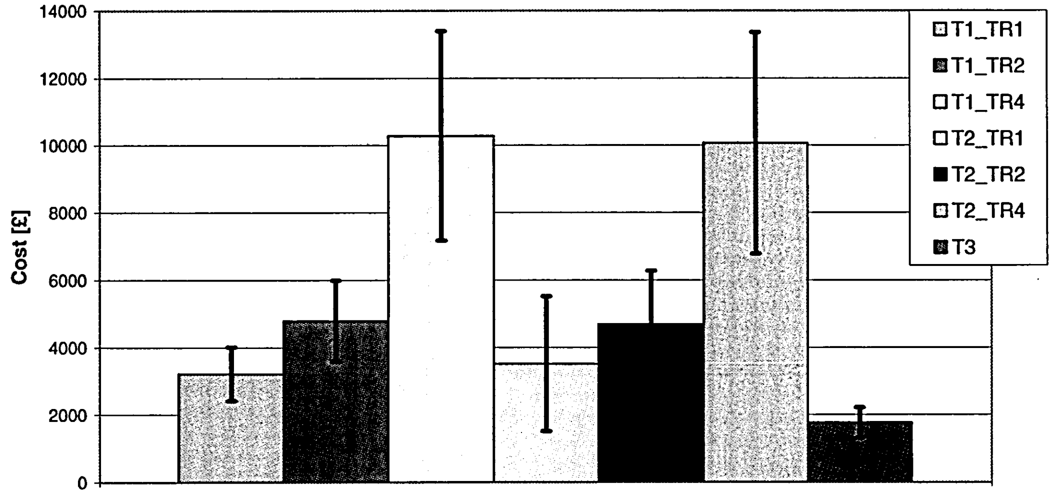

Figure 7-16 Evaluation of the Total Project Cost for the approximate process time 20

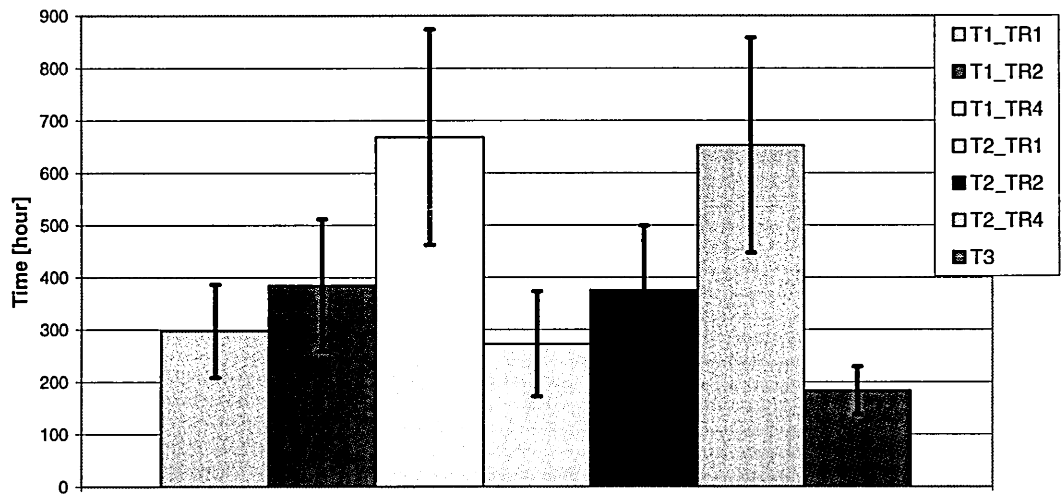

Figure 7-17 Evaluation of the Total Project Time for the approximate process time 20

	Team 1			**Team 2**			**Team 3**
Travel Time [hour]	**1**	**2**	**4**	**1**	**2**	**4**	**0**
Cost Factor [%]	182	270	582	199	265	569	100
Time Factor [%]	235	304	528	216	297	515	100
Knowledge cost [£/meetings]	402	598	1285	439	585	1258	221

Table 7-7 The calculated factors for process time 20

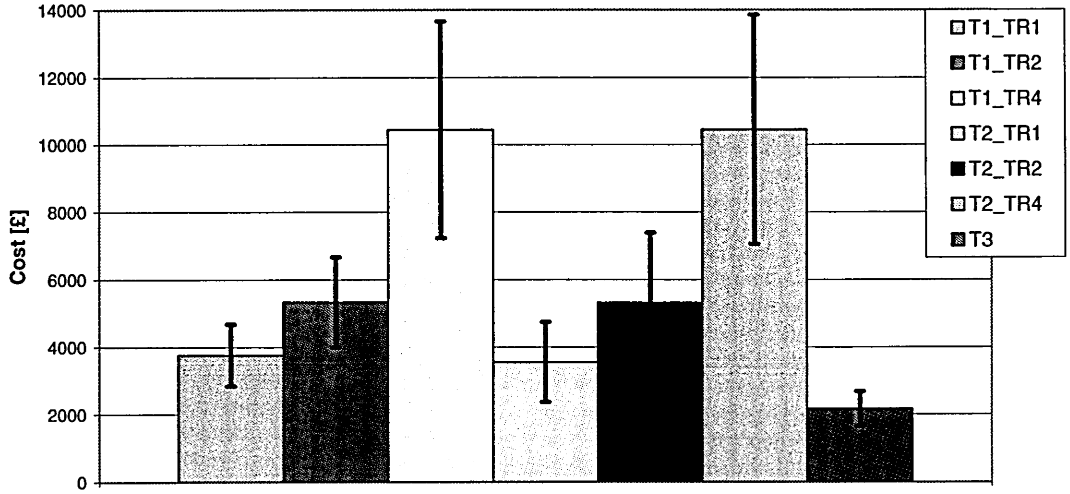

Figure 7-18 Evaluation of the Total Project Cost for the approximate process time 50

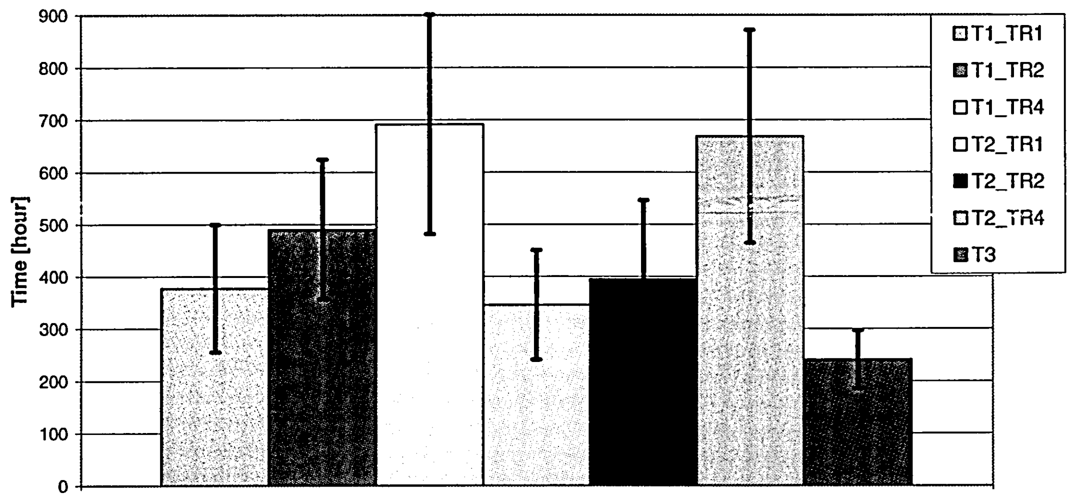

Figure 7-19 Evaluation of the Total Project Time for the approximate process time 50

	Team 1			Team 2			Team 3
Travel Time [hour]	1	2	4	1	2	4	0
Cost Factor [%]	173	245	481	163	244	481	100
Time Factor [%]	156	203	287	143	163	277	100
Knowledge cost [£/meetings]	470	666	1306	444	664	1307	272

Table 7-8 The calculated factors for process time 50

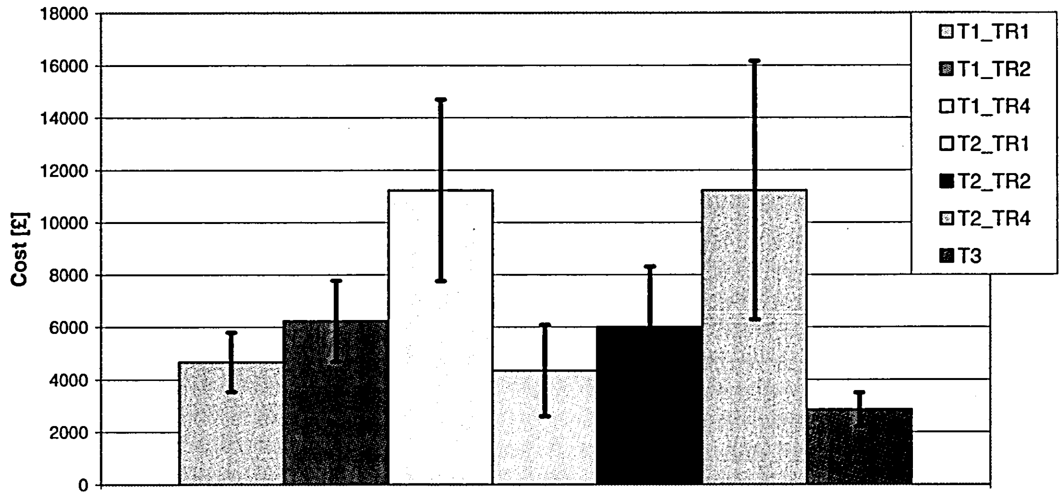

Figure 7-20 Evaluation of the Total Project Cost for the approximate process time 100

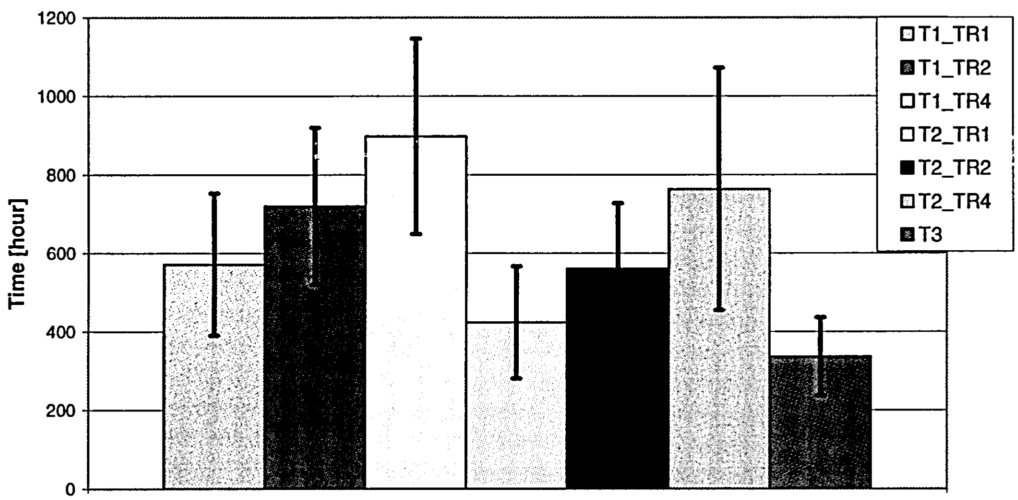

Figure 7-21 Evaluation of the Total Project Time for the approximate process time 100

	Team 1			Team 2			Team 3
Travel Time [hour]	1	2	4	1	2	4	0
Cost Factor [%]	163	218	393	152	210	393	100
Time Factor [%]	170	214	267	126	167	227	100
Knowledge cost [£/*meetings*]	583	779	1403	542	751	1403	357

Table 7-9 The calculated factors for process time 100

The results - the graphs as well as the tables; show advantages of virtual teamworking in a simulation project over a traditional face-to-face meeting. The virtual teamwork reduces the cost of the project, which can make the simulation projects more affordable. It can also reduce the project time completion that often leads to further savings, because the time between the start of a project and its conclusion decreases.

7.5 Limitation of the results

It is possible to argue that the cost analysis does not include all components. In the model of the virtual team the cost of support software and connection to the Internet are not incorporated. However, the author assumes that most companies are already connected to the Internet and use it on a daily basis to communicate with customers or suppliers, marketing, presentation, etc. Networking has become a key business factor in many businesses in order to maintain their marketplace share. Those companies already have their Web-sites, databases, and e-mail-servers, so the concept of virtual teamworking does not require extra spending on software or hardware. Moreover the author proves in Chapter 5 that it is possible to build the required support application without high spending using components freely available on the Internet.

The cost analysis involves only the direct work of the team facilitator and does not take into consideration the work incorporated with maintaining the application, and preparing the virtual meeting. However, similarly those costs were not included in the models of the traditional simulation project. Further the author argues that the virtual teamworking can bring more savings as people do not waste time during the unconstructive journeys.

7.6 Conclusions

The simulation study investigates the implications of applying the concept of virtual teamworking into a simulation project. The results show the measurable advantages of that methodology, such as project cost and completion time over a simulation project based on the traditional face-to-face meetings. The potential savings increase with the distance between project participants. The people can also benefit, as they do not have to spend so much time on travelling, and can work at a convenient time and place. The obtained results ought to help to obtain the support and help from management staff for the changes in the teamworking practises in favour of the virtual one.

The author concludes that virtual team technology may increase competitiveness of simulation companies that provide consultancy at a lower cost and lead to increase utilization of simulation techniques by opening a new market of small companies, which do not have large budget.

Whilst the managers rush to implement virtual teamwork in their organization, it is essential not to focus all effort on the technological aspects at the expense of the other important factors such as people, training and methodology.

8 Research results, conclusions and future work

This chapter presents the results of the project to address the research questions raised in Chapter 1 and Chapter 2. The issues introduced in the previous chapters are discussed, the research results are examined and the conclusions reached are presented. The last part provides suggestions for further research work.

8.1 Research question 1: "How can the Internet based solutions be applied in the life-cycle of simulation project in order to improve efficiency of the simulation team?"

The continuous development of Internet technologies has an effect on simulation methodology, and new research subjects emerged such as Web-based simulation or distributed simulation. Considering this the idea of the first research question was generated, which addressed expectations and opinions of people involved in simulation. The questionnaire survey was conducted between simulation practitioners. The results proved high expectations associated with the networking technologies. The participants indicated the distribute simulation, model documentation, and collection and distribution of input and output data, as well as simulation models as the main areas of Internet applications. The survey results also discovered that there were more expectations with networking expressed by academic staff compared to industrial practitioners. However, the questionnaire highlighted communication and collaboration possibilities offered by the Internet technologies. Those opinions that are also supported by literature review directed further research and generated following specific research questions (Chapter 2), which were addressed during the study:

(2) *How do we establish a virtual simulation team?*

(3) *How can we apply the virtual teamworking concept into the simulation project life-cycle?*

(4) *What technology should be used to support the virtual simulation team?*

(5) *What are the implications of virtual teamworking on a simulation project?*

8.2 Research question 2: "How do we establish virtual simulation team?"

The extensive literature research and author's experience in simulation, Internet technologies and teamworking established a need to develop a methodology for transforming a traditional simulation team into a virtual one. The developed new methodology formulates and standardizes the process of creating a virtual simulation team, as well as the process of carrying out a simulation project in a virtual environment. To the author's knowledge it is the first work that describes and methodises the marriage of the virtual team concept with the simulation study. The proposed approach covers the entire simulation project life-cycle and consists of three main key stages:

1. Establish a virtual simulation team
2. Collaborate using the Internet technologies
3. Project completion

The proposed methodology also considers the short, medium, and long term implications of virtual teamworking, the project management and control aspects, and the structure for virtual meetings.

The author found out that it is imperative that the virtual simulation project ought to start a traditional face-to-face meeting in order to develop people's commitment and trust, make a training session, and clarify roles and expectations. Then virtual meetings, with advanced communication and data distribution technologies can be used to discuss the progress of the project, validate models, data and results, generate ideas, and create the project's documentation, etc.

The proposed methodology allows the implementation of the broadly understood collaboration at every stage of the simulation project even though team members are geographically dispersed by carrying out regular virtual meetings. It would make it possible to involve all parties in the process such as taking decisions, developing ideas, analysing data or results, consulting each other, or looking for a support and help. However, the success of virtual simulation teamworking strongly depends on human factors - communication and collaboration skills, project commitment, knowledge and reliability; as well as on available technology.

The proposed methodology was positively validated by an empirical experiment (Chapter 6) and an analytical one (Chapter 7). The empirical trial involved implementing developed methodology in a real life situation and measuring the effectiveness of the simulation team and people's reflections on the virtual teamworking. However, in order to perform the experiment a WWW based application was developed to facilitate the virtual simulation teamworking (Chapter 5). That experiment was also used to test the developed support application, as well as to collect data to optimise and customise it.

8.3 Research question 3: "How can we apply the virtual teamworking concept into the simulation project life-cycle?"

The results of the investigation show that the virtual teamworking concept can be applied to create a virtual simulation team, which then works and collaborates over the computer network. However, it was found that there was a need to create a framework for effective utilization of virtual teamworking in a simulation project life-cycle. The author believes that effective virtual simulation teamworking is based on the fulfilment of the sixteen key principles, divided into four groups (Chapter 4.5) as simulation project, personnel, technology and team working factors (Figure 8-1 and Appendix A).

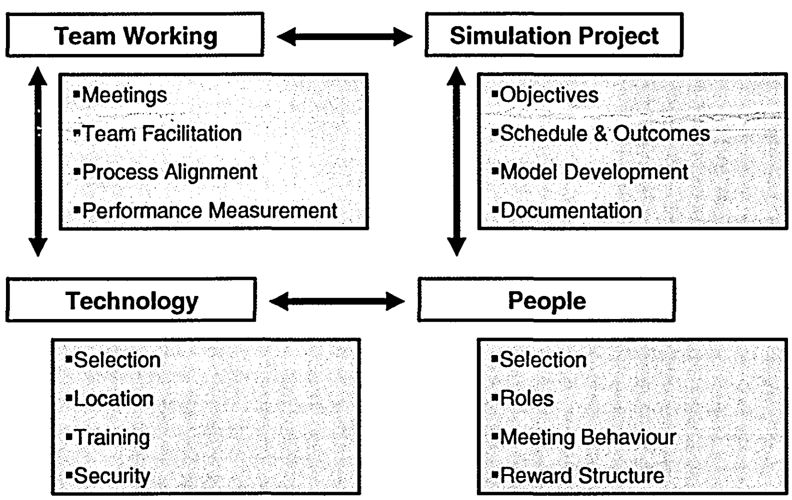

Figure 8-1 The framework for the virtual simulation teamworking

The developed framework brings to light the subjects that must be considered in the order to move the virtual simulation teamworking. The author believes that ignoring just one of presented factors may cause the strain in the virtual teamwork, antagonize people, or even make the simulation project unsuccessful.

8.4 Research question 4: "What technology should be used to support the virtual simulation team?"

The IT market offers a wide selection of available technology from specialised powerful and costly Electronic Meeting Systems to simply and cheap Groupware applications (Chapter 1.9). So the choice of technology must be based on the team needs, people's preferences, the project budget, and also incorporate factors such as social presence, information richness, hardware and software requirements and accessibility, or user environment. Applied technology must allow simulation team members to interact on an appropriate professional and social level, create an effective environment that substitutes the traditional face-to-face meetings, strengthen participants' commitment, and automate some simulation team processes such as creating documentation or distributing models and data.

During research it was decide to build our own application based on WWW standard because it is independent platform, popular and cost effective as many of tools, components and codes are freely available on the Internet. The application is based on three main components: open source Apache WWW server, MySQL database and Arena simulator. The applied components with support of e-mail and chat applications fulfil the requirements of a virtual simulation team in synchronous and asynchronous communication and collaboration, distributing and collecting data, executing simulation models, and analysing simulation results. Moreover, a modular structure of an application with dynamically created WWW-sites based on contents of data gathered in the database, make it is easy to manage and maintain.

The experiment described in Chapter 5 was used to test the developed support application, as well as to collect data to optimise and customise it.

8.5 Research question 5: "What are the implications of virtual teamworking on a simulation project?"

The research showed the explicit implications of applying the virtual teamworking concept into a simulation project. In order to get a full view analyses were made to examine relations between simulation study, simulation quality, people, knowledge management and virtual teamworking.

The author found out that the main implication of applying the virtual team concept into simulation project life cycle was the change of cooperation structure from the meetings based in traditional team to team based. The study proved that the virtual teamworking allowed intensifying the collaboration process by increasing interaction between team players irrespective of their location. Moreover, the frequent meetings, constant data flow, and involvement of every party during all project's key stages ought to raise the quality of project outputs and intensify knowledge transmission, which also increase acceptability and credibility of a simulation project.

However, it was also discovered the importance of social aspects and people factors related to the virtual simulation teamworking. The lack of face-to-face interactions requires the changes in the collaboration and cooperation practises in order to develop trust and people commitment to the project. The requirements to establish strict protocols and procedures for virtual meetings and collaboration were exposed, as well as the need for people extensive training to become an effective virtual team member.

The investigation also proved that a virtual teamworking may increase the utilization of simulation technologies by:

- Reducing the cost and completion time of simulation study by eliminating non added value processes such as paper work, travelling costs, etc
- Increasing the utilization of the simulation software by networking access to the application from remote locations
- Also simplifying the process of maintaining and updating of simulation models as it can also be done from a remote location
- Reducing the start-up cost of a simulation project should make the simulation more affordable for small companies
- Automating the creation of project documentation

8.6 Conclusions

- The study demonstrated the positive implications of applying the virtual team concept into the simulation project life-cycle with respect to technology, participants, simulation quality, and knowledge management in the simulation project.
- The research findings created the framework, which identified the important factors that must be taken into consideration during the process of formulating virtual simulation teams or transforming a traditional simulation team into a virtual one.
- The research produced the methodology, which covers the entire life-cycle of the simulation project - from establishing a virtual simulation team, through the virtual collaboration and communication over the Internet in order to achieve objectives of the simulation study.
- The investigation established the extensive need for training in order to become an effective virtual team member.

8.7 Future work

In the author's opinion, future work should be carried on in two main directions:

1. Investigate the social aspect of virtual teamworking in a simulation project
2. Develop further the technology that supports the virtual simulation team.

The research finished by validating the proposed methodology and framework for virtual simulation teamworking. However, in the author's opinion there is a need to investigate the social implications of virtual teamworking - people's opinions, relations, and experiences. An extensive survey, and based on it, case study technique, can be applied to collect data from practitioners involved in the simulation area using both traditional teams and virtual teams. Moreover, the author proposes a comparative study by developing two simulation teams - first traditional and second virtual; which would be asked to solve the same problem. Then in the second stage the teams would change collaboration techniques - the traditional one would become virtual and opposite; and face another exercise. The experiment would bring valuable data to compare the effectiveness of two teams, and members' concerns considering the team's working procedures. The results can also be useful in order to establish people's learning needs and help in creating a training course.

The developed application is based on the networking technology available during the project. As a consequence it provides only chat facilities as the main synchronous communication channel. The techniques such as videoconferencing were ruled out at that time because of the low Internet connection bandwidth, which could not efficiently transfer a smooth real-time video picture. However, emerging new technologies (e.g. broadband), and new solutions (e.g. collaborative documents editing and writing) can increase the level of interactions between project participants and endorse virtual meetings. Because of the advance in technology and the users expressed desire for a more interactive environment with the tools such as videoconferencing, or whiteboard facilities, the application must be developed further.

Reference

Avison, D. & H. Shah, (1997). The Information Systems Development Life Cycle: A First Course in Information Systems. McGraw-Hill Book Company Europe, Berkshire, England

Avison, D.E. & Fitzgerald, G., (1995). Information Systems Development: Methodologies, Techniques and Tools. 2nd edition, McGraw-Hill Publishing Company, UK.

Baker, M. (1988). Doing Social Research. McGraw Hill Book Company.

Bal, J. & Foster, P. (2000). Managing the virtual team and controlling effectiveness. International Journal of Production Research, Vol. 38, No. 17, pp. 4019-4032.

Bal, J. & Gaundry, J. (1999). Virtual teaming in the automotive supply chain, Team Performance Management, Vol. 5, No. 6, pp. 174-193.

Bal, J. & Teo, P.K. (2000). Implementing virtual teamworking. Part1: a literature review of best practise. Logistics Information Management, Vol. 13, No. 6, pp. 346-352.

Bal, J. & Teo, P.K. (2001). Implementating virtual teamworking: Part 2 - a literature review, Logistics Information Management, Vol. 14, No. 3, pp. 208-222.

Balci O. & Sargent R.G. (1984). A bibliography on the credibility, assessment and validation of simulation and mathematical models. Simulletter, Vol. 15, No. 3, pp15-27

Balci O. (1985). Guidelines for successful simulation studies. Technical Report TR-85-2, Department of Computer Science, Virginia Tech, Blacksburg, VA.

Balci O. (1994). Validation, veryfiaction, and testing techniques throught the life cycle of simulation study. Annals Operations Research, Vol. 53, pp 121-173

Balci O. (1997). Verification, validation and accreditation of simulation models. In Proceedings of the 1997 Winter Simulation Conference

Balci O., Ormsby W.F., Carr III J.T. and Saadi S.D. (2000). Palnning for verification, validation, and accreditation of modelling and simulation applications. In Proceedings of the 2000 Winter Simulation Conference.

Balci, O. & Nance, R.E. (1990). Formulated Problem Verification as an Explicit Requirement of Model Credibility. Simulation, Vol. 45, No. 2, pp. 76-78

Banks, J. & Chair, P. (2000). Simulation in The Future. Proceedings of the 2000 Winter Simulation Conference.

Banks, J., Carson, J.S. (1984) Discrete-event System Simulation. Prentice-Hall Inc., Englewood Cliffs, New Jersey.

Bender M., R. Klein, A. Disch and A. Ebert, (2000). A Functional Framework for Web-based Information Visualisation Systems. IEEE Transactions on Visualisation and Computer Graphics, Vol. 6, No. 1, January-March 2000.

Bennis, W. & Nanus, B. (1986). Leaders: The strategies for taking charge. Harper and Row, New York.

Berger M. and U. Leiner, (1997). Remote Visualisieren und Manipulieren von Simulationed im Internet. In: Proceedings of Simulation and Animation, 1-11. Society for Computer Simulation Europe, Ghent, Belgium

Bogdan, R. & Taylor, S.J. (1975). Introduction to Qualitative Research Methods. A phenomenological approach to the social sciences. John Wiley & Sons Inc., New York.

Bruzzone, A.G. (2001). Web-based simulation: Best of Websim99. Future Generation Computer Systems, Vol. 17, pp. 501-502.

Bryman, A. (1988). Quantity and Quality in Social Research. London:Routledge

Burns, R.B. (2000). Introduction to Research Methods. 4th ed. SAGE Publication Ltd.

Campion, M.A., Papper, E.W. & Medsker, G.J. (1996). Relations between work team characteristics and effectiveness: a replication and extension, Personnel Psychology, Vol. 49, No. 2, pp. 429-452.

Capron, H.L. (1986). Systems Analysis and Design. The Benjamin/Cummings Publishing Company, Inc. California, USA

Chang, R.Y. (1995) Building a Dynamic Team. Kogan Page Ltd.

Cohran, J.K., Mackalik, G.T. and Savory, P.A. (1995). Simulaion Project Characteristics in Industrial Settings, Interface, Vol. 25, No. 4, pp. 104-113.

Coleman, D. (1997). GroupWare: The Changing Environment. GroupWare: Collaborative Strategies for LANs and Intranets. Upper Saddle River, Prentice Hall, N.J.

Conwell L,C, Enright R. and Stutzman M.A. (2000) Capability Maturity Models Support of Modelling and Simulation Verification, Validation and Accreditation. In Proceedings of the 2000 Winter Simulation Conference

Cronin, M.J. (1994) Doing Business on the Internet: How the Electronic Highway is Transforming American Companies. Van Nostrand Reinhold, New York

Cronin, M.J. (1996). The Internet Strategy Handbook: Lessons from the New Frontier of Business. Harvard Business School Press, Boston, Massachusetts.

Cubert, R.M. & Fishwick, P.A. (1997). A framework for distributed object-oriented multimodeling and simulation. Winter Simulation Conference, pp. 1315-1322.

Cutkowsky M, Tenenbaum J. and Glicksman J. (1996). Madefast: Collaborative engineering over the Internet, Communication ACM, Vol. 39, pp. 78-87

Denscombe, M. (1998). The Good Research Guide for small-scale social research projects. Open University Press.

Denzin, N.K. & Lincoln Y.S. (1994). Handbook of qualitative research. Thousand Oak, SAGE Publication Ltd.

Dieng R. (2000). Knowledge Management and the Internet. IEEE Intelligent Systems, Vol. May/June, pp 14-17

Drucker, P. (1993). According to Peter Drucker. Interview published in Forbes ASAP 1993, March, pp 90-93

Duarte, D.L. & Snyder, N.T. (2001) Mastering Virtual Teams, 2nd ed., Jossey-Bass, San Francisco, CA.

Edwards K.H. & Sridhar V. (2003). Analysis of the Effectiveness of Global Virtual Teams in Software Engineering Projects. In Proceedings of the 36th Hawaii International Conference on System Sciences

Eisenhardt, K.M. (1989). Building Theory from Case Study Research. Academy of Management Review, 1989, Vol. 14, No. 4, pp. 532-550.

Ferrero, A. & Piuri, V. (1999). A simulation Tool for Virtual Laboratory Experiments in a WWW Environment. IEEE Transactions on Instrumentation and Measurement, Vol. 48, No. 3.

Fisher, K. & Fisher, M.D. (1997). The Distributed Mind, AMACOM, New York, NY.

Fishwick, P.A, Hill, D.R.C. and Smith, R. (1998). Proceedings of the 1998 International Conference on Web-Based Modelling and Simulation, SCS Simulation Series, Vol. 30, pp 10-14, San Diego, CA

Fishwick, P.A. (1996). Web-based simulation: some personal observations. Proceedings of 1996 Winter Simulation Conference, pp. 772-779.

Fishwick, P.A. (1997). Web-based Simulation. In: Proceedings of the 1997 Winter Simulation Conference.

Gass, S.I. (1987). Managing the modelling process: a personal reflection. European Journal of Operational Research, Vol. 31, pp. 1-8

Gilbert. N. (2001). Researching Social Life, 2nd ed. SAGE Publication Ltd.

Gill, J. & Johnson, P. (1991). Research Methods for Managers, Paul Chapman Publishing

Grimshaw, D.J. & Kwok, F.T.S. (1998). The Virtual Workplace. Hershey, Pa.: Idea Group Publishing.

Guru, A., P. Savory and R. Williams (2000). A Web-based interface for storing and executing simulation models. In: Proceedings of the 2000 Winter Simulation Conference.

Haywood, M. (1998). Managing Virtual Teams: Practical Techniques for High-technology Project Managers, Artech House, Norwood, MA.

Henry, J.E. & Hartzler, M. (1998). Tools for Virtual Teams. ASQ Quality Press, Milwaukee, WI.

Hirschorn, L. (1991). Managing in the New Team Environment, Skills, Tolls, and Methods. Addison-Wesley Publishing Company INC.

Jain, S. (1999). Simulation in Next Millennium. Proceedings of the 1999 Winter Simulation Conference.

Jennings L. 1997. Virtual teams transcend time and space, Futurist, Vol. 31, No. 6, September/October, pp. 59

Johnson P., Heimann V. and O'Neil K. (2001). The "wonderland" of virtual teams. Jurnal of Workplace Learning, Vol. 13, no. 1, pp. 24-29

Kalakota R. and A.B. Whinston (1997). Electronic Commerce. A Manager's Guide, Addison Wesley Longman, Reading, MA.

Kelton D.W., R.P. Sadowski and D.A. Sadowski (1998). Simulation with Arena. McGraw-Hill Book Company.

Kinlaw, D.C. (1991). Developing Superior Work Teams, Building Quality and the Competitive Edge. Lexington Books & University Associates, Inc. San Diego.

Klein, U.S., Strasburger, P. & Beikrich, J. (1998). Distributed simulation with JavaGPSS based on the High Level Architecture. Proceedings of the 1998 International Conference on Web-based Modeling and Simulation, pp. 85-90.

Kohn, A. (1993). Punished by Rewards: The Trouble with Gold Stars, Incentive Plans, A's, Praise, and Other Bribes, Houghton Mifflin, Boston.

Kuljis, J. & Paul, R.J. (2000). A Review of Web-Based Simulation: Whither We Wander? Proceedings of the 2000 Winter Simulation Conference.

Larson, C.E. & F.M.J. LaFasto (1989). Teamwork, What must go right / What can go wrong. 2nd ed. Sage Publications Inc.

Law A.M. and D.W. Kelton (1991). Simulation Modelling and Analysis. McGraw-Hill Book Company

Leigh A. and Maynard M. (1995). Leading Your Team – How to involve and inspire teams. Nicholas Brealey Publishing, London.

Lipnack, J. & Stamps, J. (1997). Virtual Teams: Reaching across Space, Time, and Organizations with Technology. John Willey & Sons, New York, NY.

Lorentz P. and P. Ritter (1997). Skopeo – A platform – independent system animation for the W3. In: Proceedings of the Simulation and Automation '97, Magdeburg, 12-23. Ghent, Belgium: Society for Computer Simulation Europe.

Lorentz P., H. Dorwarth, K.C. Ritter and T.J. Schriber (1997). Towards a Web-based simulation environment. In: Proceedings of the 1997 Winter Simulation Conference.

Lurey, J.S. & M.S. Raisinghani. (2001). An empirical study of best practise in virtual teams, Information & Management, Vol. 38, pp. 523-544.

Mayer, N. (1967) Assets and liabilities of group problem solving: the need for an integrative function, Psychological Review, Vol. 74, No. 4, pp. 385-399.

McNiff, J., Lomax, P. & Whitehead, J. (1998). You and Your Action Research Project. 2nd ed., Hyde Publication, Bournemouth, UK

Michram, D. & Michram, A. (1974). Human Knowledge, The Role of Models, Metaphors and Analogy. International Journal of General Systems, Vol. 1, No. 1, pp. 41-60

Mittleman, D.D. & Briggs B.O. (1998). "Communication technology for teams: electronic collaboration", in Sunderstorm E. and Associates, Supporting Work Team Effectiveness: Best Practices for Fostering High-Performance, Jossey-Bass, San Francisco, CA.

Mohtar, R.H., Zhai, T. & Chen, X. (2000). A world wide web-based grazing simulation model (GRASIM), Computers and Electronics in Agriculture, Vol. 29, PP. 243-250.

Montoya M.M., Massey A.P. and Song M. (2001) Getting it together: Temporal coordination and conflicts management in global virtual teams, Academic Management Journal, Vol. 44, No. 6, pp. 1251-1262

Narayanan S. (2000). Web-Based Modeling and Simulation. Proceedings of the 2000 Winter Simulation Conference.

Nastings, C., Bixby, P. & Chaundhry, R. (1986).The Superteam Solution. Billings & Sons Ltd, Worcester.

Ören T.I. (1981). Concepts and criteria to assess acceptability of simulation studies: A frame of reference. Communications of the ACM, Vol. 28, pp 190-201

Orsak G.C. & Etter D.M. (1996). Connecting the Engineer to the 21st Century Through Virtual Teaming. IEEE Transaction on Education, Vol. 39, no. 2,

Page E.H., A. Buss, P.A. Fishwick, K.J. Haeally, R.E. Nance and R.J. Paul (1998). The Modelling Methodological Impacts of Web-based Simulation. In: Proceedings of the International Conference on Web-based Modelling and Simulation, San Diego, USA.

Page E.H., R.L. Moose and S.P. Griffin (1997). Web-Based Simulation in Simjava Using Remote Method Invocation. Proceedings of the 1997 Winter Simulation Conference.

Page, E.H. & Opper, J.M. (2000). Investigating the application of the web-based simulation principles within the architecture for the next generation computer generated forces model. Future Generation Computer Systems, Vol. 17, pp. 159-169.

Page, E.H. (1998). The rise of Web-based simulation: Implication for the High Level Architecture. Proceedings of the 1998 Winter Simulation Conference, pp. 1663-1668.

Page, E.H., Moose, R.L. & Griffin, S.P. (1997). Web-based simulation in Simjava using remote method invocation. Proceedings of the 1997 Winter Simulation Conference, pp. 468-474.

Pauleen, D.J. & Yoong, P. (2001). Facilitating virtual team relationships via Internet and conventional communication channels. Internet Research: Electronic Networking Applications and Policy, Vol. 11, No. 3, pp. 190-202.

Pidd, M. (1991). OR/MS method. In M.F. Shutler (ed.) Operational research in Managemnt. Prentice Hall, Helmel Hempstead.

Pidd, M. (1992). Computer Modelling for Discrete Simulation. 2nd ed. John Wiley & Sons.

Pidd, M. (1998) Computer Simulation in Management Science, 4th ed. John Wiley & Sons, England

Quinn J.B., Anderson P. and Finkelstein S. (1996). Managing Professional Intellect: Making the Most of the Best. Harvard Business Review, March-April

Quinn, J.B. (1992). Intelligent Enterprise: A Knowledge and Service Based Paradigm for Industry. New York: Free Press

Ramesh V. & Dennis A.R. (2002). The Object-Oriented Team: Lessons for Virtual Teams from Global Software Development. In proceedings of the 35th Hawaii International Conference on System Sciences

Robinson S. & Pidd M. (1998). Provider and customer expectations of successful simulation projects. Journal of Operational Research Society, Vol. 49, No. 3, pp 200-209

Robinson S. (2002). General concepts of quality for discrete-event simulation. European Journal of Operational Research, Vol. 138, pp 103-117

Robinson, S. (1994) Successful Simulation: A Practical Approach to Simulation Projects. McGraw-Hill Book Company.

Samuelson, P. (1996). Regulation of technologies to protect copyrighted works. Communications of the ACM. Vol. 39, No. 7, pp. 17-22.

Sarjoughhian, H.S. & Zeigler, B.P. (1998). DENSJAVA: basis for DENS-based collaborative M&S environment. Proceedings of the 1998 SCS International Conference on Web-based Modelling and Simulation, pp. 29-36.

Sarker S. & Sahay S. (2002). Information Systems Development by US-Norwegian Virtual Teams: Implication of Time and Space. in Proceedings of the 35th Hawaii International Conference on Systems Sciences.

Schmidt, J.W. & Taylor, R.E. (1970) Simulation and Analysis of Industrial Systems. Richard D. Irwin, Homewood

Stangor R. (2000) Stereotypes and Prejudice: Essential readings. Philadelphia, PA: Psychology Press

Stough, S., Eom S. & Buckenmyer, J. (2001). Virtual teaming: a strategy for moving your organisation into the new millennium. Industrial Management & Data Systems. Vol. 8, pp. 370-378.

Strauss S. (1996). Getting a clue: The effects of communication media and inforamtion distribution on participation and performance in computer-mediated and face-to-face groups, Small Group Resorces, Vol.27, pp. 115-142

Suchan J. & Hayzak G. (2001) The Communication Characteristics of Virtual teams: A Case Study, IEEE Transactions on professional Communication, Vol. 44, No. 3.

Tam, E.K., Badra, F., Marceau, R.J., Marin, M.A. & Malowany A.S. (1999). A Web-based virtual environment for operating training, IEEE Transaction on Power Systems, Vol. 14, No. 3.

Taylor, S.J.E. (2000). Groupware and the Simulation Consultant. Proceedings of the 2000 Winter Simulation Conference.

Taylor, S.J.E. (2001) NetMeeting: A Tool for Collaborative Simulation Modelling. International Journal of Simulation: System, Science & Technology, Vol. 1, No 1-2, pp. 59-68

Tenner A.R. & De Toro I.J. (1992). Total Quality Management, Three steps to continuous improvement. Addison-Wesley Publishing Massachusetts

Tye, B.S. (1999) A Study on Model Design in the Simulation of Manufacturing Systems. Phd thesis, Sheffield Hallam University.

Volkoff, O., Chan, Y.A. and Newson E.F.P. (1999). Leading the development and implementation of collaborative interorganizational systems, Information and Management, Vol. 35, No. 2, pp 63-75.

VTASC Project (1999) University of Warwick http://www.wmg.org.uk/vtasc/Tech.htm. Last access 6/14/2002

Whitman L., B. Huff and S. Palaniswamy (1998) Commercial Simulation over the Web. In: Proceedings of the 1998 Winter Simulation Conference.

Yang, W.L. (1999). A distributed processing architecture for a remote simulation system in a multi-user environment, Computers in Industry, Vol. 40, pp. 15-22.

Yapa S.T.W.S (2003). A Structured Approach to Rapid Simulation Model Development. Unpublished PhD Thesis, Sheffield Hallam University

Yin, R.E. (1994). Case Study Research: Design Methods. 2nd Ed. Sage Publications.

Appendix A - The framework for applying the virtual team concept into a simulation project life-cycle

Factor	Description
Simulation Project	
Project Objectives	simulation teams must have a defined purpose, goals and clear expectations of people, which reinforces and focuses a simulation team,
Schedule & Outcomes	projects needs a timetable to keep to deadlines, and support smooth progress of all collaboration,
Model development	simulation projects are focused on building a useful model based on virtual teamworking in a collaborative way,
Project Documentation	all data, decisions and steps during the project need to be documented and available to all participants, which also supports knowledge management and transformation of tacit knowledge into a more explicit form,
People	
Selection	the simulation team members have different and specific roles to play, and, according to them, various responsibilities to fulfil,
Roles	people involved in virtual teamworking must posses not only the knowledge from their discipline but also willingness, self-consciousness and organization, high communication and cultural norms,
Meeting Behaviour	participants must communicate frequently and clearly, collaborate and openly share knowledge, opinions and ideas, respond in time and according to information, etc,
Reward Structure	to get people's commitment team and individual success must be celebrated as participants must relate the project success with their personal accomplishment and profit.
Team Working	
Virtual Meetings	the formal structure of meetings must be applied with a social convention as meetings must be organized on regular basis, allow people equal participation, to openly contribute, express concern and leave feedback, as well as give easy access to relevant information and documents,
Team Facilitation	assign a team facilitator whose role is to allocate and maintain the team's resources, but also stimulate and guide a discussion, keep and

	distribute a track of teamworking, etc,
Process Alignment	the processes from a traditional simulation team such as data collecting, model verification, model presentation, etc, have to be redesigned in order to adjust them to virtual collaboration,
Performance Measurement	the team progress must be continually monitored, collaboration processes and outcomes re-examined - that enables the review of team effectiveness, quickly detect any problems, and give space for improvements.
Support Technology	
Selection	applied technology must be selected according to project requirements and people's preference, considering the factors such as information richness, social presence, accessibility, cost, etc,
Training	in order to effectively utilize the available technology in daily activities team members must get proper training,
Location	where and how the people join a virtual meeting (special room, home, desktop PC, etc),
Security	applied technology must ensure the security of project data and collaboration processes

Appendix B – A list of papers published from that thesis

Banaszak J. and Perera T. (2001) Remote execution of simulation models using the Web. In: Proceeedings of the ICST, Szklarska Poręba, Poland.

Banaszak J., Clegg D, and Perera T. (2003) Application of virtual team concept in simulation. In: Proceedings of the ICMR, Glasgow, UK

Banaszak J., Clegg D, and Perera T. (2003) Remote execution of simulation models. In: Proceedings of the ICMR, Glasgow, UK