2. Participative Simulation in the PSIM Project

Frans M. VAN EIJNATTEN [1] & Peter VINK [2]

[1] *Eindhoven University of Technology, Faculty of Technology Management, Pav.U10-T&A, P.O. Box 513, 5600 MB Eindhoven, The Netherlands, Tel.: +31 40 247 24 69; Fax: +31 40 243 71 61; E-mail: F.M.v.Eijnatten@tm.tue.nl*
[2] *TNO Arbeid, P.O. Box 718, 2130 AS Hoofddorp, The Netherlands, Tel.: +31 23 554 95 90; Fax: +31 23 554 93 05; E-mail: P.Vink@arbeid.tno.nl*

Abstract. This chapter describes the background and objectives of the IST project Participative Simulation environment for Integral Manufacturing enterprise renewal (PSIM). In the short run, PSIM aims to address the key issues that have to be resolved before a manufacturing renewal can be implemented. PSIM is focused on intelligent manufacturing in order to unleash human creativity supported by ICT technology. The long-term goal of PSIM is to show simulated assembly lines in a software environment. PSIM can be used to enable a participative improvement process involving specialized staff, management and production personnel. This chapter gives an overview of some basic ideas that provided both the theoretical and conceptual basis for the PSIM project.

2.1 Introduction

2.1.1 Participation and Democracy

Contemporary requirements put on companies to fulfill the needs of their clients and shareholders are numerous and high at the same time. Consequently, the challenge is to be innovative in markets and maximize efficiency. However, as was expected by many commentators, manufacturing enterprises find themselves in a highly competitive and global market place at the start of the 21st century. In order to survive, these firms have to optimize their productions at an ever-progressing rate. In doing so, they have to confront a multitude of stakeholders' demands. In order to turn an innovative prototype into a manufacturable product at a much higher speed than ever before, companies need to continuously improve the process of product creation. At the same time, resulting prototypes of new products should fit in manufacturing systems that cost effectively can produce them.

In their struggle to cope with those new demands, most modern organizations are well underway to become knowledge-based enterprises. The above-mentioned trends presuppose the explicit managing of knowledge creation and knowledge processing. Drucker [1] and Quinn [2] – two researchers who pioneered in the field of Knowledge Management – advocate, that knowledge should be seen as a prime resource for competitive advantage in current and future competition. They emphasize that the management of knowledge should be coordinated at the highest level, preferably at the level of the company as a whole. Of course, this managerial activity is not executed in a vacuum. The political context is of major importance here.

A democracy can be seen as the dominant socio-political regime in all developed countries, nowadays. Democracy is defined as a system of governance in which people actively take part in the decision-making process. Two archetypes can be distinguished: Representative Democracy and Participative Democracy.

Representative Democracy is defined by Emery [3: p. 1] as *"choosing by voting from among people who offer themselves as candidates to be our representatives."* Participative Democracy is defined by Emery & Emery [4: p. 100] as *"locating responsibility for coordination clearly and firmly with those whose efforts require coordination."*

Within a democratic system participation of employees easily can take multiple forms. In a company context participation is defined as a process which allows employees to exert some influence in improving their work and the conditions under which they work [4]. According to Heller et al. [4: p. 45] competence (capability) is: *"both a requirement for and a consequence of participation."* It is a requirement because participation needs a minimum level of skills in order to be effective. At the same time it is a consequence because participation enhances the skills levels of those involved. Participation as a process has advantageous results for both the individual – in terms of capability and job satisfaction, and for the organization – in terms of core competence, increased efficiency and higher effectiveness.

In a *Representative Democracy* the influence of people on decision-making is rather indirect. This form, we call 'political participation,' is defined by Abrahamsson [6: pp. 186/189] as *"participation involving the right to control organization's executive (...) / involvement in high-level goal setting and long-term planning."*

In a *Participative Democracy* the influence of people on decision-making is as direct as possible. This form, we call 'socio-technical participation,' is defined by Abrahamsson [6: p. 189] as *"participation in the organization's production, i.e., in the implementation of decisions taken on higher levels."*

Representative Democracy and Participative Democracy can both be concurrently present in an enterprise, on different levels of aggregation. Familiar examples are the Works Council functioning at the higher or enterprise level, and self-managed work teams operating at the lower or shop-floor level. In a literature survey on Participatory Ergonomics [7] another more practical aspect of participation is stressed: direct involvement of the end users and groups influencing the improvement process increases the chance of successful implementation.

2.1.2 Participative Simulation in Manufacturing Design and Process

End-user involvement in design and innovation is increasingly being advocated. Proponents argue that a participative approach can have important benefits for both the end users and the organization as well. In particular, two direct advantages are commonly referred to. First, there is the point that end users have unique knowledge and experiences of their work. Their involvement will, therefore, provide a clearer understanding of both the types of problems being encountered, and the solutions that will be appropriate. Second, involving end users in analysis, development and implementation of a change will generate greater feelings of solutions' ownership, and thus may breed a greater commitment to the changes being implemented [7].

As said before, in organizational design and management ever more attention is paid to successful improvement processes, enabled by socio-technical participation [8]. Some benefits of direct participation are recognized in its contribution to a smooth mutual communication between management and employees. Socio-technical participation may be considered in the development, the implementation and the application of an improvement project. To boost direct participation, it is recommended to allow the employees to establish cross-departmental task teams – which deal with improvement issues – and to engage in 'participative simulation.' The European Foundation for the Improvement of Living and Working Conditions [9: p. 2] reports that direct participation in organizations most often leads to quality improvements (90% of the cases), to reduction of throughput times (60% of the cases), and to reduction of costs (60% of the cases).

In 'participative simulation,' workers exert direct influence over the product and process designs by bringing in their tacit knowledge – to combine it with expert knowledge – and to put the blend of both insights to the test. The moment these experimenting and problem-solving activities are supported by an attractive ICT interface, the resulting continuous improvement process may become even more intrinsically motivating for the work force [10]. Besides, it also will contribute to the competitive advantage of the enterprise.

Participative simulation can help to improve the work of a manufacturing work force. A powerful integrated digital environment that would bring to life a virtual copy of the actual manufacturing system represents an interesting facility [11] [12] [13]. It would enable profound analysis of possible interventions in the real manufacturing system, and ensure more efficient improvement efforts [14].

In participative simulation, the applied tools should as well produce images (mere descriptions) of all sorts of designs, as be able to compare their respective qualities (evaluations) and suggest improvements (reflections, and regulative actions). In order to accomplish that, the tools should be upgraded to expert bases. Although the technical aim in advanced intelligent manufacturing systems is to accomplish a more predictable work system, experiences from the social sciences indicate, that especially where humans are concerned, absolute norms and solid predictability are limited, and centralized control is not more than a utopia.

In PSIM, holistic thinking ('looking at the whole') and analytic thinking ('looking at the parts') are combined, at different levels of aggregation. At the highest level, an image of the whole system is created, and its functioning in its environment is evaluated ('looking outwards'). At the lower levels, parts and their inter-relation-ships are distinguished and analyzed in detail ('looking inwards'). It is the aim of the specially designed ICT architecture to guarantee that all sorts of simulation tools can be easily plugged in, in order to support the processes of analyzing and synthesizing in a context of dialogue. The idea is to tap and store both the explicit and implicit knowledge of the employees. In Box 2.1 Participative Simulation is defined.

The goal of Participative Simulation in general, and of the respective simulation tools in particular is not to deliver factual solutions to the users, but rather to support them to reflect on their work situation, and to elaborate their own tailor-made solutions.

Participative Simulation is:

- *A dialogue environment for the exchange of tacit and explicit knowledge about the design and control of production systems,*
- *A dialogue environment for the development or renewal of workplaces,*
- *An ICT environment which supports dialogue between workers of different levels in the organization,*
- *A means to stimulate thinking processes about renewal,*
- *A groupware tool,*
- *A management information system,*
- *A game to develop common understanding of organizations,*
- *Based on an integral approach.*

Participative Simulation is not:

- *A mathematical tool,*
- *An optimalization tool,*
- *An actual individual simulation (though simulation can be used in participative simulation as a tool),*
- *A generic system,*
- *Based on a fragmented approach.*

Box 2.1 A Definition of Participative Simulation

2.1.3 Intelligent Manufacturing Systems and Assembly Operations

Although the idea of participative simulation is not new, the potential of this method in organizations was rather restricted, for a long time. It is the development of modern ICT technologies that expands the participative simulation potentials with an order of magnitude. The local knowledge of workers, locked in their traditions and work habits, may be successfully tapped and communicated by using ICT-supported participative simulation. For instance, the intended ICT-enhanced participative simulation prototype will be multi-media: it will use narratives, photos, videos, computer graphics, illustrations, figures, games, performance indicators, and animations. It can be used both by managers, technical staff and workers as well.

Up until the present day, the total number of users of simulation tools in the domain of work organization has been pretty low. In so far simulation tools were used to reflect on possible interventions, they were often stand-alone and did not support an integrated perspective on possible changes to practice. One of the major problems was and still is to generate a common description, e.g. a future workstation or situation on the shop floor in the existing plant, and let people from different backgrounds participate in the analysis. In the past, these tools often reflected a state of the business that was already outdated.

The decreasing level of specificity in the material components of manufacturing systems which are based on openness and modularity, implies that the competitive advantage of the system as a whole has to be found elsewhere: The human operator and his working methods came to stand out more prominently. It is known, that these work methods develop on the basis of complex and unique 'know-how' based on organizational cultures and strategies, and consequently, are not easily imitated [15] [16].

The centrality of the human factor calls for 'Intellectual Capital Management'. Although Intellectual Capital Management has received a lot of attention in professional service organizations – and evolved there into a hype – it has been almost completely neglected in assembly. If a company wants to make efficient use of knowledge and intends to cause the knowledge, skills and experience of its employees to become more effective with respect to achieving organizational goals, the two perspectives on Intellectual Capital Management – organizational and individual competencies – should be aligned. The two perspectives become compleenary to each other. Unfortunately, current theory does not provide much guidance on how to accomplish that.

Typically, most researchers on core competencies are not explicitly stating their level of analysis: They do not clearly distinguish organizational from individual competencies. Core competencies are discussed as collection and integration of skills and technology of a company as a whole (across diverse business units). Individual employees are seen as the 'skills carriers' that embody the competencies [17] [18]. Theorists recognize that in practice a mechanism for allocating skills is seriously lacking. Hamel and Prahalad [17: p. 89] write: *"We find it ironic that top management devotes so much attention to the capital budgeting process, yet typically has no comparable mechanism for allocating the human skills that embody core competencies."* But they do not discuss any method or approach how to fill in the role of individual capabilities, with respect to strategic objectives and competencies of an enterprise. A similar conclusion can be drawn from literature on individual capabilities: A clear connection with organizational goals and core competencies is lacking.

To take a step forward, we propose an approach based on the idea that the power of knowledge is not so much leveraged by exclusively possessing that knowledge. It is far more important to know, how to allocate knowledge for productive use [1]. Nonaka and Takeuchi [19: p. 59] discuss the role of an organization in allocating knowledge as follows: *"The organization supports creative individuals or provides contexts for them to create knowledge. Organizational knowledge creation, therefore, should be understood as a process that 'organizationally' amplifies the knowledge created by individuals and crystallizes it as a part of the knowledge network of the organization."* The successful execution of this organizational activity can be regarded as a core competence.

To become a competitive strength, the work methods should reflect all manufacturing expertise that is available in an organization, not only the insights of a privileged process engineering elite. In the design of new systems, or reconfiguring of existing ones, interdisciplinary participative reflection should be encouraged and supported, to influence the manufacturing organization primarily as a knowledge processing entity. In order to accomplish this goal, strategic action through investments in a proper environment is needed. Computerized facilities for 'participative simulation' could be instrumental in this respect.

ICT can support communication by providing highly visual representations of abstract processes, which conduce to a common ground for dialogues. In this respect, 'simulation' is defined as the construction and use of a computer based representation or model of some part of the real world as a substitute vehicle for experiment and behavior prediction. It offers an attractive opportunity for engineers, planners, managers and production teams to try out ideas or commitment to a course of action, in advance [20].

2.2 Contribution to Intelligent Manufacturing Systems

2.2.1 The PSIM Project

PSIM is an Information Society Technology (IST) project sponsored by the Fifth Framework initiative of the European Commission that develops and pilot-demonstrates a Participative Simulation environment for Integral Manufacturing enterprise renewal. PSIM runs under the umbrella of the HUMACS program. HUMACS is an abbrevation of Organizational Aspects of HUman-MAchine Coexisting Systems, and is part of Intelligent Manufacturing Systems (IMS), a global industry-led Research and Development program. The PSIM/HUMACS consortium consists of twelve European, eight Japanese, four American and three Canadian partners.

PSIM aims at the development of a simulation environment for use in assembly operations, and wants to advance integral renewal in a competitive, changing environment by supporting continuous improvement processes. In this project simulated assembly lines are developed and pilot-demonstrated in a software environment, involving both specialized staff, management and production personnel as well. By the end of the PSIM project a structure for the software environment as well as a process of implementation have been developed which are proven to be operational in three European-Union pilot sites. Also they have been studied with other HUMACS partners, including other potential PSIM users in the European Union, Switzerland, Japan, and the USA. We expect a 15% efficiency improvement at the three pilot sites and 20% better work satisfaction due to better working conditions, in about two years. Another expectation of the PSIM project is, that the process of participative simulation can be shortened and be made of a much higher quality because of the integrated use of ICT technology.

In order to test the basic ideas, the PSIM project will actively engage into a reality check, using several industrial test sites in Europe, Japan, and the USA. To demonstrate the concept, PSIM will concentrate on expertise from the domains of Socio-Technical Systems Design and Ergonomics. The first key design methodology is *Socio-Technical Systems Design (STSD)*, which is concerned with the optimization and integration of the human factor in manufacturing systems, predominantly at the work group, departmental and organizational levels. It aims at improving the quality of work and organization, simultaneously, through adaptation or fundamental re-design of contents and composition of technology and human tasks [21]. The Dutch STSD variant of Integral Organizational Renewal (IOR) offers dedicated design concepts, methods and strategies. These can be used for diagnosing and improving existing production structures in order to make optimal use of the human factor, while at the same time enabling a multitude of design objectives (i.e. innovation, flexibility, controllability and quality of work). STSD can successfully support ICT-driven simulation of organizational renewal in a development activity game environ-ment. Within the socio-technical framework, also a method was developed that specifically addresses the issue of allocating tasks between humans and technology, i.e. defining the degree of automation. Key to this so-called KOMPASS method, that was developed at ETH, are design criteria at the level of the work system, the individual task, and the human-machine interface, which can be used in system modeling and simulation [22] [23]. KOMPASS also focuses on the design of indi-vidual work tasks by using theories about work psychology such as action theory, and theories about work motivation.

While the focus of the socio-technical framework is on the human-technology interaction, the more specific aspects of fitting tasks and technology to human operators is dealt with by the second key design methodology, the *Ergonomic Approach*, which is concerned with optimizing the tasks, technical systems and work stations in order to improve human performance and to reduce mental and physical workloads. Data from the European Foundation for the Improvement of Living and Working Conditions [9] indicate that a rise in 'time pressure' has taken place throughout Europe. Approximately 30% of the workers in the European Union are involved in painful and tiring postures for more than half of their working day and 40% of the workers are exposed to short repetitive tasks, which often lead to reduced quality, productivity, complaints or even sick leave. A recent survey reports on the work-relatedness of drop out from work due to psychological dys-functioning. Some important aspects in the reduction of workload are the good fit between task and personality, possibilities to develop and regulate your own work. Therefore an important function in PSIM is envisioned that will warn users when unacceptable workload for humans and teams is anticipated in a particular work system design. Users of PSIM will be warned for physical and mental hazards in designs of a work-flow or workstation.

2.2.2 Method

The PSIM project followed a systematic approach, based on two phases:

- *Development of the PSIM Prototype:* The PSIM prototype was built by nine partners: five European universities (TU/e, Eindhoven, The Netherlands; RWTH, Aachen, Germany; Chalmers, Göthenburg, Sweden; UOP, Patras, Greece; and ETH, Zürich, Switzerland); two research institutions (TNO, Hoofddorp, The Netherlands; FIOH, Helsinki, Finland); and two software developers (Baan, Barneveld, The Netherlands; GFI Consulting, Turin, Italy). The PSIM prototype was built in four main work packages: Ontology, Navigator, Tools, and Integration, over a period of one and a half years,

- *Test of the PSIM Prototype:* The test of the PSIM prototype was prepared in two work packages: Pilot Requirements and Pilot Demo, using the 'Focus-Migration' method. Three industrial partners participated in the test: Finland Post, Helsinki, Finland (logistic industry); Volvo, Göthenburg, Sweden (automotive); and Fiat, Turin, Italy (automotive). Each of them offered one single pilot site for testing and studying the developed prototype. In the context of HUMACS two additional companies offered opportunities to test the PSIM tool: Yamatake, Tokio, Japan (electronic industry); and Ford, Detroit, USA (automotive). The test site requirements were determined by using an inductive method ('as is' analysis of tasks, work organization, and work roles), and the derivation of demands for PSIM (assembly development, ergonomic and socio-technical assessment) was achieved by means of a survey.

The PSIM prototype was tested in the before-mentioned five companies – using the Ergotool and / or STSD tool – addressing only one single PSIM goal (improvement). The PSIM prototype was explicitly developed and prepared for these individual tests, only. The rationale behind this was that the consortium wanted to test the feasibility of the principle ('proof of concept'), in the first place.

2.2.3 Results

The Participative Simulation (PSIM) prototype that was developed, consists of a number of integrated parts. The complete tool contains an innovative ICT environment composed of an ontology, a procedure or navigator, and an OLAP (On-Line Analytical Processing) integrator, a set of specific work organization analysis and design tools (i.e., with respect to Ergonomics and Socio-Technical Systems), and a well-developed handbook in which detailed procedures for alternative applications are worked out in detail. In it the user will find an extensive description of the settings for, the conditions of, and the individual tools in the PSIM prototype.

The PSIM environment consists of a state-of-the-art ICT architecture that enables both technical communication between the different tools databases and access for different users by providing a user interface that is sensitive to the individual profiles, jobs, tasks and specific work contexts. It supports an integral approach by relating models and data to a virtual copy of the actual, imagined, or proposed manufacturing system. The ontology thus encourages integration, which is focused on the holistic consideration of human, organizational and technical aspects. The navigator enacts the PSIM procedure by providing the right tool, with the right data, in the right place, and with the best user interface. Between the tools and the navigator a communication layer is built to insure the coherence of the exchange of data between the individual tools. The PSIM-user roles as mapped in the navigator are explicitly defined in a way that supports inter-disciplinary work in project teams.

The individual tools that are worked out in detail, are exclusively dealing with Ergonomics and Socio-Technical Systems Design. They offer users opportunities to self-assess and self-design their work systems and methods of work, preferably in a multi-disciplinary work group context. The aim is to reach consensus regarding design goals and solutions. The tools allow its users to store analysis and evaluation data and outcomes, thus enabling the users to keep track of changes and effects of changes for a particular work process.

The PSIM handbook explains to the user in simple language how the PSIM environment works, what sorts of applications are possible, which specialized tools are available, and what kind of solutions they may provide. The PSIM procedure shows different applications, i.e., continuous improvement, renewal, fast innovation, and implementation of new methods of work, and guides the users towards the right tools. For each of these applications it presents respective steps to follow in a 'deep slice' project group, using a participative approach. As an extra, it offers some help with respect to time management, and illustrates the procedural integration of the work of different project groups. Embedded in the PSIM procedure is a general enterprise model. The PSIM procedure consists of three phases: 1) Defining current problems and future objectives for which solutions must be designed or found, and selecting or marking out respective work systems which need further consideration; 2) Detailed analysis, assessment, and evaluation of the work system(s) under consideration; 3) Creation or selection, elaboration and evaluation of tailor-made design solutions.

Initially, the Ergo- and STSD tools were developed into paper-and-pencil prototypes with manual functionality, limited-use procedures and provisional user support. They were tested in individual workshops at Finish Post and Volvo. On the basis of these tests the prototypes were refined and prepared for ICT support.

The refined PSIM procedure and the ICT-supported versions of Ergo- and STSD tools were tested in three companies at the end of 2002. In all test sites the PSIM procedure proved to be an essential part. Both steps of analyzing the existing situation and discussing ideas for improvement with a group of engineers, operators, management and designers were evaluated positively. In evaluating the procedure companies mentioned that a facilitator is very much needed. The Ergonomic and Socio-Technical Systems Design experts proved to be essential in the processes of inviting the users to follow the procedure, and in explaining some backgrounds of the simulation. Also, the visualization support (by use of a video) was evaluated positively. Actual tools differences were observed between companies. Companies that were not used to apply Ergonomics evaluated the Ergo tool more positive then those who were. The application of the mental workload module in the Ergo tool, and the application of the STSD tool resulted in the largest number of new improvement ideas. Both tools were evaluated very positively. Other parts of the tools were nice, but it was the question whether they would replace existing checklists, methods or software that are already used by companies. Also, it was mentioned that the application of the STSD tool was rather time consuming.

2.3 Conclusions

It is expected that the PSIM project will produce a breakthrough in both Participative Simulation method and ICT architecture, including the ontology (see Chapter 3). It is anticipated, that the ICT architecture will enable other knowledge domains to be integrated in the PSIM tool as modules quite easily. A potential candidate for inclusion is the Design of Workspace decision-making model that resulted from the Brite-Euram III, Work-space II Thematic Network BET2-516, 4^{th} Framework Program [24], that will add decision-making about facility management to the Participative Simulation environment.

The lessons learned thus far concentrate on the topics of interdisciplinary preparation and communication. It appeared a necessity to visit the test sites with a full multi-disciplinary team, in order to research the requirements, in order to develop and test the tool appropriately. During the development of the ontology, major differences in concepts and methodologies among the experts came to the fore. The readiness to take enough time to dialogue about these issues extensively, proved a prerequisite to solve these issues. It offered a basis for a successful completion of the PSIM project.

As to main barriers for adoption, a problem could be the overall attractiveness of the simulation tool for the end users, or the modest level of penetration of computers in assembly operations. Also, the generality of the tool may be questioned, in specific assembly environments.

2.4 Discussion

The PSIM project was a big success, both from an ICT point of view (see Chapter 3), and from an organizational learning perspective, as well. Participative Simulation appeared to be a powerful way to involve people in the renewal of their enterprise.

Also from a national cultures perspective the usability of PSIM was interesting. Hofstede distinguishes between four basic dimensions that characterize national cultures [25]: the orientation to authority (power distance), the integration of individuals in groups (individualism / collectivism), the actual distribution of roles between sexes (masculinity / femininity), and the preference for stability (uncertainty avoidance). Extensive research by Hofstede revealed that national cultures differ on those four dimensions, significantly [25]. Cultural differences may have influenced the usability of the PSIM tools in either Europe, Japan or the USA. Finland and Sweden are classified by Hofstede as extremely feminine cultures, while Japan, Italy, and the USA are characterized as more masculine cultures, resulting in more individual competition. Power distances are moderate in most before-mentioned countries except for Finland where preferences for equality are extremely high, resulting in democratic leadership and minimal centralisation. Individualism is highest in the USA, Italy and Sweden, resulting in individual based incentives, and moderate in Finland and Japan. Uncertainty avoidance is highest in Japan, and lowest in Sweden, influencing differentially the degree of formalization and personal risks.

Although all PSIM tool tests were administered in an open and friendly atmosphere, some cultural effects may have been observed, embedded in the specific work organization context.

References

[1] P. Drucker, The New Productivity Challenge, *Harvard Business Review*, **Nov-Dec**, 1991, pp. 69-79.

[2] J.B. Quinn, Intelligent Enterprise: A Knowledge and Service Based Paradigm for Industry, The Free Press, New York, 1992.

[3] F.E. Emery, Toward Real Democracy, Ontario Quality of Working Life Centre/Ministry of Labor, Toronto, 1989.

[4] F.E. Emery, and M. Emery, Participative Design: Work and Community Life, Part 1-3, in: M. Emery (Ed.), Participative Design for Participative Democracy, Australian National University, Centre for Continuing Education, Canberra,1989, pp. 94-113.

[5] F. Heller, E. Pusic, G. Strauss, and B. Wilpert, Organizational Participation: Myth and Reality, Oxford University Press, 1998.

[6] B. Abrahamsson, Bureaucracy or Participation: The Logic of Organization, Sage, Beverly Hills, 1977.

[7] H.M. Haines, and J. Wilson, Development of a Framework for Participatory Ergonomics, HSE Books, 1998.

[8] P. Vink, The Process of Improving Productivity by Worker Participation, in: Proceedings of the 13^{th} IEA Congres, Volume I: Organizational Design and Management, Finnish Institute of Occupational Health, Helsinki, 1997, pp. 453-56.

[9] European Foundation for the Improvement of Living and Working Conditions, Communique July / August, 1999.

[10] R.J. van den Berg, G. Grote, and P. Orban, Participative Simulation for Assembly Operations: A Problem Statement, ISATA, 99ADM059, 1999.

[11] J.O. Riis (Ed.), Simulation Games and Learning in Production Management, Chapman & Hall, London, 1995.

[12] M. Forssen-Nyberg, Simulation Games – The State of the Art and the Future, in: Proceedings of the 13^{th} IEA Congress, Volume I: Organizational Design and Management, Finnish Institute of Occupational Health, Helsinki, 1997, pp. 49-52.

[13] J.B.M. Goossenaerts, A Framework for Connecting Work and Information Infrastructure. In: J.B.M. Goossenaerts, F. Kimura, and J.C. Wortmann, (Eds.), Information Infrastructure Systems for Manufacturing, in: Proceedings of the IFIP TC 5 Conference on the Design of Information Infrastructure Systems for Manufacturing (DIISM'96), Chapman & Hall, London, 1997.

[14] G. Bruno, C. Reyneri, and M. Torchiano, Enterprise Integration - Operational Models of Business Processes and Workflow Systems, in: K. Kosanke, and J.G. Nell (Eds.), Enterprise Engineering and Integration: Building International Consensus, Research Report Esprit, Springer Verlag, Berlin, 1997.

[16] NRC (National Research Council), Committee on Visionary Manufacturing Challenges, Visionary Manufacturing Challenges for 2020, National Academic Press, Washington DC, 1998.

[17] G. Hamel, and C.K. Prahalad, Competing the Future, Harvard Business School Press, Boston, 1994.

[18] K.P. Coyne, S.J.D. Hall, and P.G. Clifford, Is Your Core Competence a Mirage?, *The Mc-Kinsey Quarterly*, **1**, 1997, pp. 40-54.

[19] Nonaka, and H. Takeuchi, The Knowledge Creating Company, Oxford University Press, New York, 1995.

[20] P. Groumpos, P. and J. Krauth, Simulation in Industrial Manufacturing: Issues and Challenges, in: D. Fichtner, and R. Mackay (Eds.), Facilitating Deployment of Information and Communications Technologies for Competitive Manufacturing, The European Conference of Integration in Manufacturing - IiM, Dresden, 1997.

[21] F.M. van Eijnatten, and A.H. van der Zwaan, The Dutch IOR Approach to Organizational Design: An Alternative to Business Process Re-engineering?, *Human Relations* **51**(3), 1998, pp. 1-30.

[22] G. Grote, A Participatory Approach to the Complementary Design of Highly Automated Work Systems, in: G. Bradley, and H.W. Hendricks (Eds.), Human Factors in Organizational Design and Management - IV. Elsevier, Amsterdam, 1994, pp. 115-120.

[23] G. Grote, T. Waefler, C. Ryser, and A. Windischer, KOMPASS: A Method to Aid Complementary Design of Automated Systems, in: Proceedings of the First International Workshop on Intelligent Manufacturing Systems, Lausanne, 1998, pp. 577-594

[24] F.M. van Eijnatten, and J.A. Keizer, An Inductive Model for Holographic Decision Making in Industrial Workspace Design, *International Journal of Management and Decision Making*, 2002, forthcoming.

[25] G. Hofstede, Culture's Consequences: Comparing Values, Behaviors, Institutions, and Organizations Across Nations, Sage, London, 2001.