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SUPPORTIVE ROLE OF THE SIMULATION IN THE PROCESS OF SHIP ENGINE CRANKCASE PRODUCTION PROCESS OF REENGINEERING (CASE STUDY)

Paweł Pawlewski
Paulina Golińska
Marek Fertsch

Institute of Management Engineering
Poznan University of Technology
60-695 Poznan, Poland

Jesus A. Trujillo

Dep.Automation and Systems
University of Valladolid
E47008, Valladolid, Spain

Zbigniew J. Pasek

Dep Industrial Syst. Engineering
University of Windsor
401 Sunset Avenue Windsor, Canada

ABSTRACT

The following paper presents the results of a case study conducted in a company producing engines for ships. The scope of the research enhances the elaboration of the method of reengineering the production process with the support of simulation. Authors present the background of the research including the comparative analysis of five different reengineering methodologies. On analysis, the conclusion is defined that there is a gap in reengineering methodologies since they do not account for industry-based requirements for simulation. To fulfill this gap the Petri nets application for simulation was proposed. Authors discuss the most distinctive elements of a Petri net and define the methodology of manufacturing processes modeling. The obtained output was not sufficient to make a final decision about the real reengineering process. Therefore, an additional analysis with Rapid RE (Rapid Reengineering) methodology was performed. The proposal of the potential hybrid solution combining the advantages of both methods, i.e. Petri Net and Rapid Re, is presented.

1 INTRODUCTION

In the analyzed company the need for a reengineering of the production process of a ship engine crankcase was identified. Applying simulation to the reengineering process was beneficial as any changes in the real production process are connected with serious costs, due to a big size of the product and application of the highly specialized processing tools. The aim of the simulation was to provide the guarantee that the chosen solution would be suitable for the analyzed company. To perform a simulation, it is necessary to collect process data, right simulation and analysis. For the reengineering process it is proper to perform a simulation for the actual state of the process and for the postulated state – in other words – to perform a simulation before and after the reengineering. The Petri net methodology was applied in creating the simulation. To collect data for the postulated state Rapid Re methodology was used. The research conducted in the analyzed company proved that the most suitable solution for a similar problem would be a hybrid method combining features of a Petri net and Rapid Re.

The paper is organized as following: in Section 2 a discussion of the main approaches to the reengineering is performed and a gap in the use of the simulation is shown. In section 3 the production process of a ship engine crankcase is identified. In Section 3 theoretical background of the research regarding Petri nets is presented and the developed simulation procedure is discussed. In Section 4 Rapid Re methodology is described and in section 5 the comparison of both methods is provided. Final conclusions and further works are stated in Section 6.

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2 DISCUSSION OF MAIN APPROACHES TO REENGINEERING

Based on the literature study, five different approaches to reengineering can be identified (Cempel 2005):

- Hammer/Champy approach (Hammer and Champy 1993)
- Manganelli/Klein approach (Manganelli and Klein 1998)
- Tichy/Shermann approach (Tichy and Sherman 1993)
- Davenport approach (Davenport 1993)
- Durlik approach (Durlik 1998)

The first two approaches can be classified as consulting ones, the third approach is purely managerial. The last two approaches can be classified as mainly academic (Cempel 2005).

The concept of reengineering owes its popularity to Hammer/Champy and their 1993 book, "Reengineering the Corporation" (Hammer and Champy 1993). In their book, Hammer and Champy quote three factors which, in their opinion, delineate modern business world and set up the framework for reengineering, namely: customers, competition and change.

The key role in this approach to reengineering is played by information technology as a change-enabling factor. According to Hammer, a fundamental mistake most businesses make in their approach to technology is to look at it from the point of view of the existing processes. One of the major difficulties in this method is to think of new, yet unknown features of the technology, which entails a change from deductive into inductive reasoning. In practical terms, this means an ability to find an effective solution first, and only then to look for problems to be solved with it.

Even though the authors did not attempt to develop a consistent methodology, some general phases can be identified which go into a reengineering project (Table 1).

In their work The Reengineering Handbook : A Step-by-Step Guide to Business Transformation (Polish edition, Reengineering. Metoda usprawniania organizacji" Manganelli and Klein 1998), R.L. Manganelli and M.M. Klein described a step-by-step process of how to streamline an organisation. The book is one of few publications which take up the concept of reengineering in a methodical manner, and its authors wanted it to become a practical tool to be used in organisations.

The Rapid Re™ methodology consists of 54 steps clustered in 5 stages (Table 1), with each completed stage forming a project milestone. Individual steps are illustrated in the book, with a fictitious ABC Toy Company Ltd serving as an example.

The authors believe their methodology is designed to deliver quick results. Its starting point are objectives of a reengineering project, needs and expectations of management and stakeholders, and customer needs. What is not specified are actions to be taken to correlate the current strategic objectives of a business with the objectives of a reengineering project.

The authors call their method Rapid Re™ and it is designed to enhance operating processes rather than tactical or strategic ones, such as proper market selection or designing proper products for a given market.

The authors advise against any thorough analysis of existing processes and warn against analytical paralysis. It is enough to understand a process, and there is no need to analyse it thoroughly.

One of the most difficult issues is the selection of processes for reengineering. The authors use the following criteria in the process selection:

- impact: current and potential impact of each process on business goals,
- size: resources used by each process,
- scope: time, costs, risk, and social changes connected with reengineering of each process.

N.M. Tichy and S. Sherman present their method in the book "Control Your Destiny or Someone Else Will" (Tichy and Sherman 1993). The book tells a story of Jack Welch and his successful attempt at diverting General Electric from its business decline. As a result of Welch's management concepts, the company nearly doubled its revenue, tripled its net income, and boosted its productivity by more than 400%.

The leading idea behind that concept is to effect revolutionary changes in a business on an ongoing basis. Tichy formulated five principles to be followed when effecting changes within a business:

1. One should understand how "business mechanisms" work.
2. One should understand the importance of human relations.
3. No compromises should be made in pursuing one's goals.
4. One should be open to change.
5. One should have a "hard head" and a "soft heart".

The method comes with a large number of useful forms. A "business test" is used to assess what degree of "revolution" a business needs. A "readiness test" checks whether managers and their teams are ready for a "revolution". The most fundamental idea within GE was that every GE company should be "number one or number two in the world".

The method makes a reference to a revolution. Welch used the so-called "police" (internal financial audit service) and controlled internal and external media as well as internal education system (Crotonville training centre).

To ensure maximum involvement of personnel in the transformation process, group work sessions were held ("Work-Out" sessions) with participants from all corporate levels and functions. The sessions were led by specially trained employees and/or external consultants. Initially, the team focused on busting excessive bureaucracy. Later on, organisational processes were examined, the areas of key significance identified, and redundant processes scraped. Also, simpler and better ways of working were looked for, and organisational processes were benchmarked.

Davenport (Davenport 1993) distinguishes between process improvement and innovation. By its nature, improvement is a continuous process ensuring incremental effects. Time required to bring about improvements is relatively short, improvements have a narrow scope and the related risk is moderate. In terms of participation, improvement is a bottom–up process. Innovations, on the other hand, are radical and revolutionary. Existing processes only serve a background, and new processes are started from a clean slate. In terms of participation, innovations are top-down processes, changes they bring about are broad and cross-functional, and the related risk is high, which is characteristic of reengineering.

According to Davenport, a key factor in reengineering is to formulate a business vision and process redesign objectives such as cost reduction, employee satisfaction or process duration cuts.

Davenport (Davenport 1993) suggests that process reengineering teams should focus on a few key processes (up to 15 at most).

In contrast to Hammer and Champy, Davenport proposes a thorough analysis of a selection of existing processes. This is to rule out that any older solutions are discovered anew.

He suggests that a particular attention be devoted to an implementation stage as it has an essential impact on the final project results. Approximately, this stage takes twice as much time (at least one year) as any previous stage.

Davenport also suggests that reengineering be combined with less revolutionary process-based approaches, e.g. with Total Quality Management.

In the method proposed by I. Durlik (Durlik 1998), proper reengineering steps are preceded by a strategic and economic analysis of a business. Afterwards, a decision is made concerning redesign and product positioning. Individual stages of the reengineering methodology are shown in Table 1.

Durlik suggests that reengineering projects should be selected based on a profit criterion. In this context, profit does not have to be determined in a traditional way: it might be a cost reduction, cost reimbursement or an increased sales potential.

Table 1: Reengineering methods as per individual phases of an organised activity (Cempel 2005)

	Qualification phase	**Research and optimal solution selection phase**	**Realization phase**	**Inspection and evaluation phase**
M. Hammer / J. Champy	1. Introduction 2. Process identification 3. Process selection for reengineering 4. Understanding of selected processes	5. Clean slate design of selected process	6. Implementation	
R.L. Manganelli / M.M. Klein	1. Preparation 2. Identification 3. Developing a vision	4. Solution design: a. technical aspect b. social aspect	5. Transformation	
N.M. Tichy / S. Sherman	1. Awakening 2. Developing a vision	3. Design and reconstruction	*(4. Implementation is part of phase 3)*	
T.H. Davenport	1. Developing a vision and objectives 2. Process identification 3. Understanding and analysing processes	4. Use of information technologies 5. Creating process prototypes	6. Implementation	
I. Durlik	1. Setting a project task 2. Preparing a process map and setting the scope of further work	3. Radical redesign of selected processes 4. Simulation and option assessment 5. Selecting best option	6. Implementation	7. Controlling 8. Continuous improvement

For business process description, process maps and dependency charts are used, prepared both for individual products and on a company-wide scale.

In terms of process modelling, Durlik considers two model types:

a) Technical: which includes physical parameters of a process (area, machinery, energy factors and raw materials),

b) Economic: which primarily includes two parameters – time and capital.

The choice of the best solution option is made based on the principle "the greatest benefit with the smallest change and at the lowest cost".

Durlik introduces controlling as a tool to control and monitor budget performance. Durlik believes that failure to address this issue in the past has led to cost overruns and serious organisational problems. Based on input from the controlling functions, reengineering teams should dynamically introduce changes to the project.

The author introduces the concept of "dynamic business reengineering" (DRB) which denotes the idea of permanent reengineering-based changes.

The analysis of the presented reengineering methodologies indicates a number elements they have in common. We use a cycle of organized actions defined by Le Chatelier (Cempel 2005) as the base point for the analysis. This cycle is composed of the following phases:

1. Goal choice
2. Research of resources and conditions for goal realization
3. Resources and conditions preparation
4. Goal realization.
5. Results inspection

Based on this reasoning we can distinguish four phases :

1. Qualification phase
2. Research and optimal solution selection phase
3. Realization phase
4. Inspection and evaluation phase

Table 1 presents reengineering methods according to the defined phases. The presented order indicates a concetration of activities at the initial stages of the methods. It confirms that the initial stages are the sources of success in 80% cases (Vilfredo Pareto principle). However, this order shows one more thing, i.e. in most methods the inspection and evaluation phases are not clearly distinguished – only in Durlik's methodology this phase is defined, yet without determining tools or instructions.

Conclusions to Section 2: only Durlik's method (Durlik 1998) shows a need for the use of simulation to assess individual options; however, on closer analysis, the need for simulation is only indicated, without any hints given on how to proceed with it. There is no description of simulation tools or methodology. On analysis, we can conclude that there is a gap in reengineering methodologies since they do not account for industry-based requirements for simulation.

3 IDENTIFICATION OF SHIP CRANKCASE MANUFACTURING PROCESS.

The project was based on 6RTA62U ship crankcase manufacturing process. The engine is manufactured by HCP (Hipolit Cegielski Poznan) and licenced by Warstsila. It is a slow-rotation two-stroke engine for cargo ships. The engine works with the speed of 92 to 115 rpm. The engine has 6 cylinders, diameter 620 mm. The horsepower of the engine is 15 550. Its size is 10.63 m of hight, 5.25 m of width and 7.5 of lenght. The manufacturing cycle is about 7-8 months. Figure 1 presents the crankcase element of a ship engine and figure 2 and 3 present operations: welding of whole and treatment.

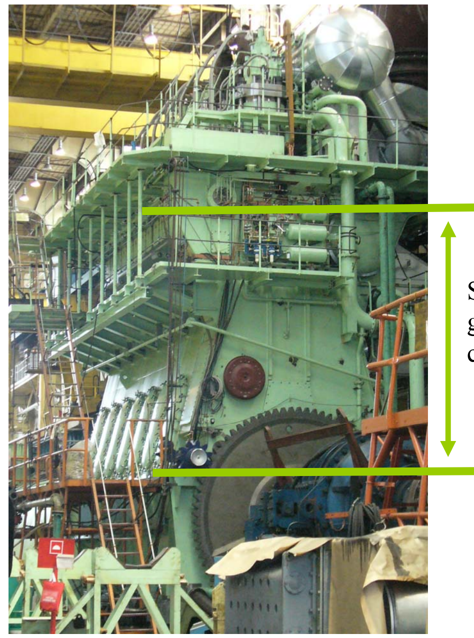

Figure 1: Crankcase element of ships engine. (source: HCP)

At the stage of identification a process card is designed . It is a fundamental template for data collection, as it includes activities carried out within the ship engine crankcase manufacturing process. Based on the information presented in the form of process cards, a process map can be developed. IDEF0 methodology is a tool for map drawing up.

Figure 2: Ships engine crankcase - welding of whole(source: HCP)

Figure 3: Ships engine crankcase – treatment operations(source: HCP)

Figure 4 presents the main processes of ship crankcase construction process:

1. Burning
2. Execution of prow part
3. Execution of stern part
4. Joining prow and stern parts
5. Treatment

The whole process is composed of 58 operations.

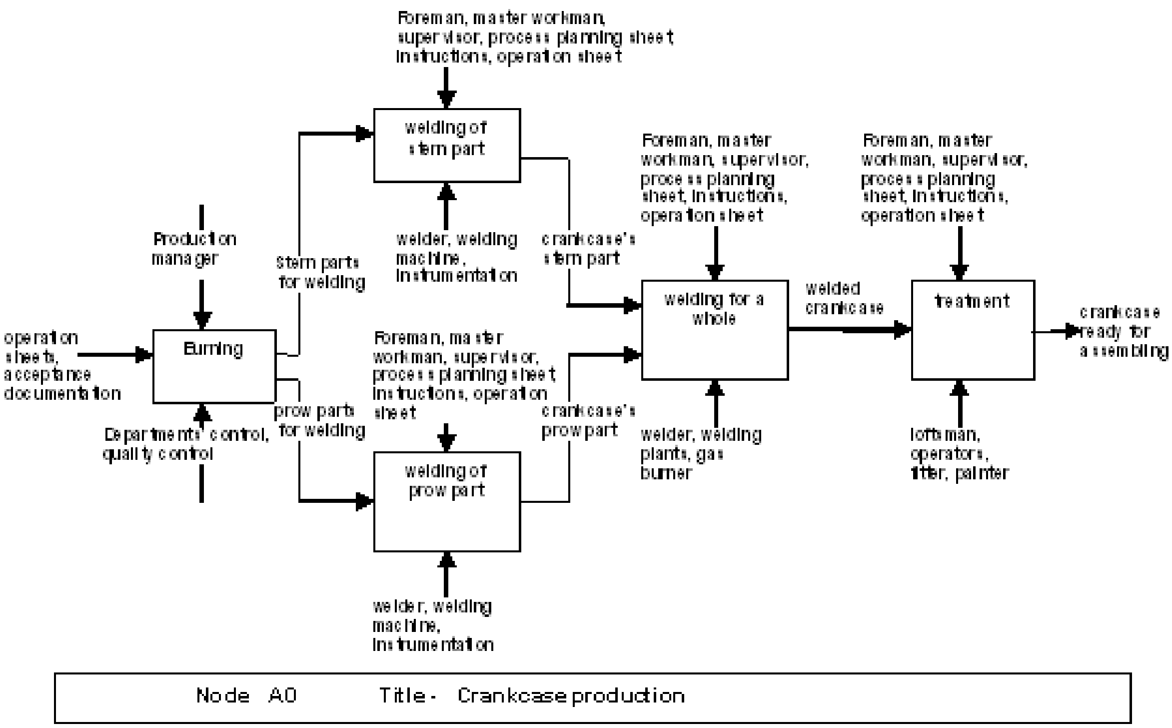

Figure 4: Graph of five main sub-processes in ship crankcase manufacturing process (source: HCP)

4 METHODOLOGY WITH SIMULATION BASED ON PETRI NET

A Petri net (Aalst and Desel 2000; Chen 1990; Peterson 1981, Reisig 1988) is one of the several mathematical representations of discrete distributed systems. As a modeling language, it graphically depicts the structure of a distributed system as a directed bipartite graph with annotations. As such, a Petri net has place nodes, transition nodes, and directed arcs connecting places with transitions. Petri nets were invented in 1962 by Carl Adam Petri in his Ph.D. thesis.

Nets enable a survey of system features and they are applied for a description and study of information processing systems. Their theory is becoming one of the basic research directions. They are mostly applied in data analysis, software engineering, work organization, parallel programming. Lately a large number of research and theoretical works concerning the application of a Petri net in the business process modeling has been published (Aalst and Desel 2000). These publications provided a strong impetus for the project presented.

For the purpose of modeling the ship crankcase manufacturing process with a Petri net the following procedure has been drawn up:

STEP I Choice of the process that is to be modeled
STEP II Definition of the initial stage – In this case initial stages are technological processes and process maps.
STEP III Definition of the place- places represent such factors as: communication methods, conditions or states. In the analyzed process the following places are distinguished: finished sheets, burning process.
STEP IV Definition of transitions– Transitions define such variables as shifts, events, transformations e.g. burning process, control.
STEP V Definition of tokens - Tokens represent such objects as: human resources, machines, goods, states of objects, conditions, information, state indicators (e.g. indicator of the state in which a process or object is)
STEP VI Modeling of relations between places, transitions and tokens with tree graphs. It consists of a division of crankcase manufacturing process into successive production stages, which are parts of ship crankcase manufacturing process. They are connected with arrows.
STEP VII Definition of attainable states – an attainable state is a state which can be achieved from the current state, arising because of starting the sequence of possible shifts i.e. shifts between tokens and transitions. In the analyzed case the attainable states are: burning process, manufacturing process of the crankcase stern part, manufacturing process of the crankcase prow part, process of joining prow and stern parts.
STEP VIII Definition of dead states – a dead state is a state in which no shift is possible. Such states are not distinguished in the conducted research.
STEP IX The model is transferred to VisualObject Net software.
STEP X Conclusions and evaluations.

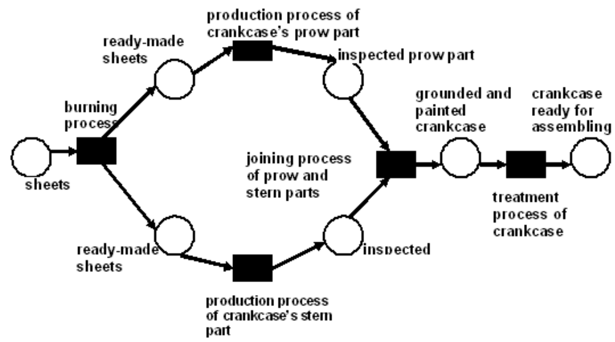

Figure 5: Crankcase manufacturing process(source: HCP)

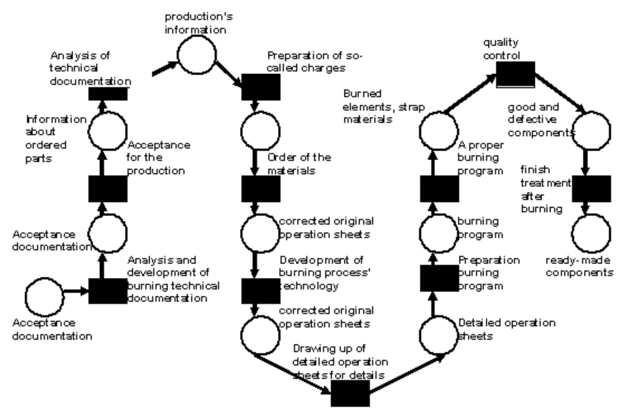

Figure 6: Burning process(source: HCP)

Figure 5 and Figure 6 present models for main crankcase manufacturing process and burning process.

The application of Petri nets made it possible to collect valuable information about production process structure and provided suitable basis for the simulation. However, the obtained output was not sufficient to make a final decision about real process reengineering. Therefore, an additional analysis with use of another reengineering methodology was required.

5 ADDITIONAL RESEARCH BASED ON METHODOLOGY RAPID RE.

Based on the discussion presented in section 2 the Rapid Re methodology was chosen. The main arguments for this selection are:

- suitability for the improvement of the operation processes, yet not for the tactical or strategic ones
- the most methodological approach - described precisely
- the literature on the subject provides many examples of detailed problem-solving solutions.

This methodology consists of five stages:

1. Arrangements – this stage concerns such matters as making the Board accept the project, defining purposes of the project, composing the project team, determining skills of the team members, team training, changing the plan of development.
2. Identification - concerns mostly processes in an organization, their connections to supplier and customer processes, process modeling, preparation of the map of the organization and sources.
3. Creating a vision - the stage which is an estimation of the existing processes, their influence on general effectiveness, the strategy of the change implementation and the estimation method with use of benchmarking.
4. Solution project – technical aspect – the use of technical sources and technology in modifications and – social aspect – the method of human resources transformations.
5. Transformation – methods of work progress inspection, success estimation, pilot tests.

Investigations show that according to Rapid Re methodology, the procedure of correcting a crankcase manufacturing process was elaborated.

Stage 3 – creating a vision – this stage (Klein and Manganellii 1998) identifies the actions which create added value; these are actions thanks to which something is created or appreciated by customers, actions of inspection and others. These actions were compiled in tables for each main sub-processes.

Example of a Burning process is presented in table 2. Based on the tables with classified activities, the actions ratio which generates the added value was enumerated in the relation to a general number of actions.

In the next steps the factors which influence the effectiveness of the process and potential sources of errors and problems were described.

Based on the information collected before, the possibility of process modification was estimated. The modification was evaluated considering the range of modification and difficulties in execution.

Table 2: Classification of the activities in a burning process- fragment

No	Activity	Type of activity		
	Burning	**Value-adding**	**Inspection**	**Other**
1	Acceptance to production			X
2	Technical documentation analysis		X	
3	Charge preparation			X
4	Order of materials			X
5	Preparation of precise operation sheets of details		X	
6	Developing the burning program		X	
7	Burning process + transport	X		
8	Inspection		X	
	....			

The expected costs of the modification was assessed as well as profits arising from them. The range of advancement was evaluated as well as the risk which arises from introducing the modification.

The estimation of the possibility of reengineering is presented in Table 3.

Accomplishment of the up-to-the-present works let to specifying the vision of the "ideal" process i.e. describing performance of the process when all the parameters are optimal. The execution of basic actions the process is composed of was defined in order to make ideal.

RAPID RE methodology is appropriate mainly for business processes, that is why quite a few problems occurred when it was adjusted to reengineering of the production process of the ship crankcase. The method is very responsive to errors connected with compiling data. It is seen particularly in counting the ratio of the actions which bring added value to all actions. In the analyzed case its high value is caused by time limitations. They have resulted in compiled data based mainly on technological documentation instead of being based on the direct observation. However, compact and specified vision of the process was successfully offered and enabled reengineering definition. It seems that further works should be directed to defining more strict requirements connected to the quality of the compiled data in order to have no doubt when calculating the factor which is the measure of the potential of redesigning the process. On the other hand, it seems to be impossible to build a formal model of the process so that it could be simulated and the results of the redesigning would be observed.

Table 3: Estimation of the possibility of the ship crankcase production process rationalization - fragment

Possibility of reengineering	Modification	Difficulty	Advantages	Risk
Elimination of faults which occur during order reception and technical documentation analysis	Electronic order reception currently brought up to date	Moderate	Accuracy, less work	Low
Fine sentencing for unpunctual orders completing	Modifications in agreements signed with subcontractor	Moderate	No delays	May not succeed and as a result lead to a subcontractor change
Optimization of COBURG III utilization	Preparattion of adequate production schedule	High	Cost reduction of equipment operation	Well qualified production planners
Elimination of faults which appear when appointing a date of executing actions included in the whole process	Making a proper time-scale production	High	Time reduction of crankcase production	Well qualified production planners
Quality inspection carried out adequately early after delivering the annealed crankcase to a subcontractor	Quality inspector checks up the delivered crankcase	Low	No possibility of receiving the wrongly annealed crankcase	Low

6 CONCLUSIONS AND FURTHER WORKS

Investigations based on Petri nets and Rapid Re methods presented in the previous section has shown that none of them entirely fulfills the company requirements for the production process reengineering. The method based on Petri nets is a suitable tool for identifying the process structure as well as an adequate framework for simulating the analyzed process before and after reengineering. Rapid Re method is not appropriate for simulation; it also lacks the possibility for time analyses of the operations and the classification of activities is not sufficient for a complex production process. The biggest advantage of Rapid Re methodology is the fact that it provides a framework for a reengineering process design and organization. Its procedure is very precisely described in the literature and many examples of detailed problem-solving solutions are given. Rapid Re provides tools and methods for making an assessment of the processes appropriateness, as well as a comparison of the activities in the process.

The research conducted in the analyzed company has shown that a hybrid solution is needed for reengineering a complex production process. The hybrid solution should combine the advantages of both methods. The Rapid Re methodology should be extended by the following elements:

a. transition of a process map into a process model based on Petri nets in order to gain the possibility of analyses and synchronization of parallel activities.
b. supplementation of activity-based indicators used in Rapid Re, by the introduction of time-based indicators
c. extension of Rapid Re activities classification (value adding, inspection, other) by the classification applied in ASME methodology developed by the American Society for Mechanical Engineers (Cempel 2005) :

- value adding operations,
- operations which do not add any value,
- quality and / or quantity control,
- transport, flows of people, materials, information, documents, etc.,
- downtime, temporary storing, delay or — idle time between operations,
- storing which is not downtime.

The presented idea of a hybrid solution states the base of a new methodology which will be investigated and described. There are plans to continue this work in collaboration with the ship engines factory where our research began.

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AUTHOR BIOGRAPHIES

PAWEL PAWLEWSKI works as an Associate Professor at the Department of Computing and Management, Poznan University of Technology. He holds a PhD in Mechanical Engineering, specialization "organization of production systems" from the Poznan University of Technology. His research interests include organization of manufacturing systems, monitoring of operations management, reengineering and IT application for logistics His e-mail address is <pawel.pawlewski@put.poznan.pl>.

PAULINA GOLINSKA is an assistant researcher at the Department of Computing and Management at Poznan University of Technology. She holds MSc. in Mechanical Engineering from the Poznan University of Technology and MBA from the joint program of University of Warsaw and University of Illinois at Urbana Champaigne. Her current field of research includes: production planning and control in uncertainty conditions, operations management monitoring, crisis management and material flow management. Her e-mail address is <paulina.golinska@put.poznan.pl>

MAREK FERTSCH is a Professor at the Department of Computer Science and Management at the Poznan University of Technology. He holds a PhD and DSc in Mechanical Engineering from the Poznan University of Technology. His research interests include manufacturing systems, production planning and logistics. He is a member of ISIR. His e-mail address is <marek.fertsch@put.poznan.pl>

JESUS TRUJILLO is an Associate Professor at the Automation and Systems Department of Industrial Engineering at the University of Valladolid (Spain), and Assistant Research Scientist in Cartif Technological Research Center. He has been Visiting Scholar at the University of Michigan. He holds PhD in Industrial Engineering from University of Valladolid. His research interests include control logic, discrete event systems, supervisory control, production planning, and scheduling with emphasis in reconfigurable manufacturing environments and large-scale systems modeling, optimization. He is a member of IEEE. His e-mail address is <jestru@eis.uva.es>

ZBIGNIEW J. PASEK is an Associate Professor at the Department of Industrial and Manufacturing Systems Engineering at the University of Windsor. He holds a PhD in Mechanical Engineering from the University of Michigan. His research interests include manufacturing systems automation, risk management, health care engineering and informal engineering education. He is a member of IEEE, ASME, SME, and ASEE. His e-mail address is <zjpasek@uwindsor.ca>.