DYNAMIC SIMULATION OF PRODUCT PROCESS

Lasse T. Pesonen [1], Simo J. Salminen [1], Jean-Peter Ylén[2], Pasi Riihimäki[2]

[1]Nokia Corporation,
P.O.Box 50, FI-90571 Oulu, Finland
lasse.pesonen@nokia.com (Lasse T. Pesonen)
[2]VTT, System Dynamics
P.O.Box 1000, FI-02044 VTT, Finland
peter.ylen@vtt.fi (Jean-Peter Ylén)

Abstract

During 90's Nokia utilized Concurrent Engineering (CE) process in mobile phone business successfully. Strong growing of the company, more complex technologies, maturing markets and changes in competition has increased the need to develop the Product Process of the company to keep its position as an agile, innovative and productive product developer. Dynamic simulation approach has been one of the activities among other Product Process re-engineering efforts in the company.

This paper describes the approach and "Product Process Decision Simulation" (PPDS) solution as the first implemented application of the approach. A dynamic model of product development has been created and applied to manage Product Process complex dynamic behavior on system level in order to reduce product development cycle times, slippages and costs as well as improve perceived product quality. The key contribution of the simulation solution is to provoke facilitated discussion in order to gain shared understanding of interdependencies and dynamic causes and effects in Product Process.

The implementation and frequent simulation workshops have started in June 2006 and over 300 R&D people have already participated.

Keywords: Management flight simulators, System dynamics, Product process, Decision making, Training.

Presenting Author's biography

Dr. Lasse T. Pesonen is working as a Senior Manager in Product Process Architecture Solutions team for Nokia. His work experience covers 10 years in Steel Industry automation and past 13 years he has worked for Telecom Industry manufacturing and product development. He has earlier published conference papers in the field of Production Control, Activity Based Management and Production Automation. He has Ph.D (Tech.) from Department of Process and Environmental Engineering, University of Oulu. Address: Nokia, Yrttipellontie 6, 90230 Oulu, FINLAND.

ISBN 978-3-901608-32-2

1 General

During 90's Nokia achieved a leading market position utilizing Concurrent Engineering (CE) process successfully in its product development. Strong growing of the company, maturing markets and changes in competition has put increasing pressure to develop Product Process system of the company to keep its position as an agile, innovative and productive product developer. Dynamic simulation approach has been one of the activities among other Product Process development efforts in the company.

This paper describes the approach and "Product Process Decision Simulation" (PPDS) solution as the first implemented application of the approach. A dynamic model of product development has been created and applied to manage Product Process complex dynamic behavior on system level in order to reduce product development cycle times, slippages and costs as well as improve perceived product quality. The key contribution of the simulation solution is to provoke facilitated discussion in order to gain shared understanding of complex interdependencies and dynamic causes and effects in Product Process...

2 Modeling of complex product process

2.1 Background

System Dynamics has been applied to product processes by several researchers. Ford and Sterman published the basic principles of system dynamic modeling of product development processes in 1998 [1]. The model they developed was calibrated to a semiconductor chip development project.

Repenning *et al.* have published several papers on the subject of fire fighting in product development [2,3,4]. Their research showed that multi-project development cycles are very susceptible to this self-reinforcing phenomenon.

Optimization on strategic level of product development was presented by Boyer and Elter in [5]. Their research dealt with achieving minimum time for profitability.

Lee and Peña-Mora have applied system dynamics to iterative error and change management [6,7]. They applied their model to construction processes – in particular a design-build highway project in Massachusetts.

2.2 Basic modules of the system dynamic model

The dynamics of software projects have been treated in detail by Abdel-Hamid and Madnick [8]. The model presented in this paper uses the concepts presented in [8] in a number of its sub models.

The simulator was based on simple generic modules, e.g., the simplified work model shown in fig. 1. Similar models have been documented by numerous authors – a good reference is Sterman [9]. There are sub models for workforce, quality, productivity, stress, etc. The dynamic model was constructed with Vensim® software.

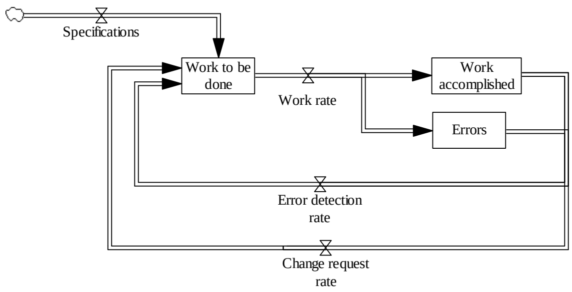

Fig. 1 A simplified generic work model

The model consists of nonlinear differential equations, the states of which consist of balance equations on the following type

$$\frac{dW_{tbd}}{dt} = r_{sp} + r_{ed} + r_{cr} - r_w , \qquad (1)$$

where W_{tbd} is work to be done, r_{sp} is specification rate, r_{ed} is error detection rate, r_{cr} is change request rate and r_w is work rate.

The change rates are nonlinear functions depending on a number of factors. Typically, the rates form multiplicative structures, i.e., "The weakest link" structures as follows

$$r_w = N_{wf} \cdot P_{wf} , \qquad (2)$$

where N_{wf} is the size of the workforce and P_{wf} is the productivity of the work force.

These variables are determined, in turn, by other sub models. The size of workforce depends dynamically on the workforce allocation model and productivity on, e.g., the stress and workforce experience models.

Many static nonlinearities, typically gained from company experts and experience, are formulated as table functions.

2.3 The structure of the model

The simple work modules are connected in parallel (portfolio) and in series (supply chain) – altogether there are more than 50 work modules in the game version of the simulator – forming a relatively accurate representation of the Nokia product process.

The model simulates 10 product programs in detail and 30 surrounding product programs. Each product is build using simple work models (fig. 1) Work inside the programs was further segmented to different categories, such as, planning, execution, error correction, to name but a few. In the simulation the

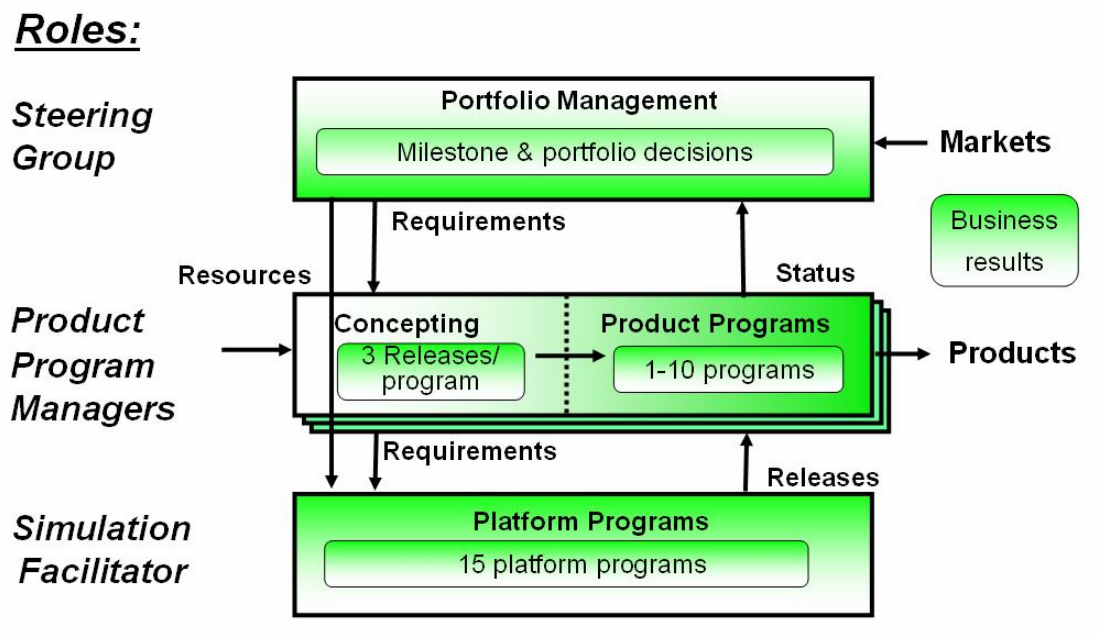

Fig. 2 Simulation scope and decision roles

product process is managed on two hierarchy levels - product program and portfolio management decisions. The hierarchical structure is shown in fig. 2.

Products are built to meet the specifications and requirements given by the steering group (portfolio decisions).These requirements contain both functional requirements (e.g., camera, browser) and business targets (BOM-costs, launch dates, etc.)

For each of the products there are building blocks consisting of software, electro mechanics and engine . Each of these classes can be divided into several subcategories e.g., electro mechanics is divided into monoblock and fold designs as shown in fig. 3. Each subcategory consists of a number of releases varying in contents and availability at a given date.

Each release is produced with a similar work model as shown in fig. 1, which means that the logistic chain deals with probabilities – everything affects everything. The decisions made by steering group, product managers, configurations, etc. determine the flow of the simulation.

Internally the relevant variables are connected to work and tasks and these are controlled with specifications and resources. Important metrics are reported – most significant of these deal with time, quality and money.

Different resources, financial structures, crude market scenarios and finished product attributes e.g. attractiveness to potential customers have been included in the model as well. The model was tuned and validated with real measured data and with input from Nokia product development experts.

2.4 Simulation workshop example

The minimum time for a simulation workshop is about three hours, but normally 4 hours is reserved for a session. The product configuration takes some time and the first couple of simulation rounds are slow. But

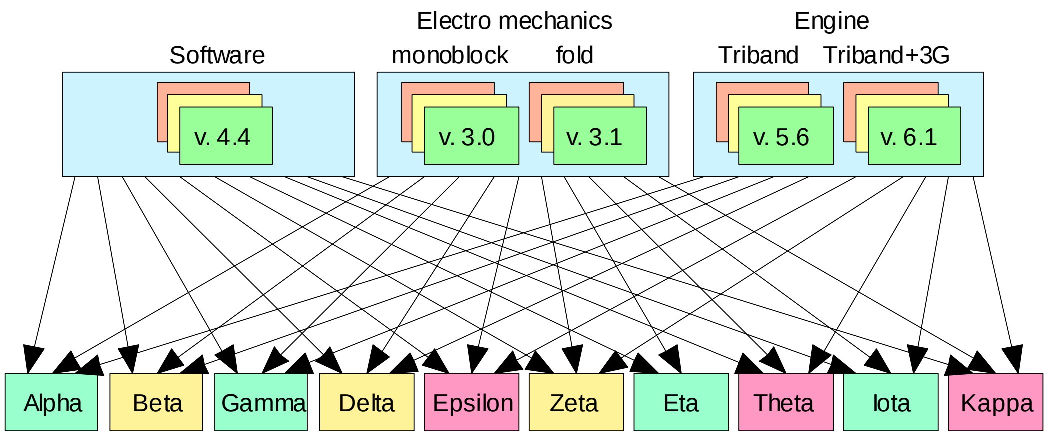

Fig. 3 Building blocks for simulated Products

	Alpha	Beta	Gamma	Delta	Epsilon	Zeta	Eta	Theta	Iota	Kappa
Program PD0 w	60	64	60	64	72	72	68	64	68	64
Mission	Quality	Time	Quality	Time	Cost	Time	Quality	Cost	Quality	Cost
Software	4.5	4.5	4.6	4.5	4.5	4.5	4.5	4.6	4.5	4.5
Engine	6.1	5.8	6.2	5.7	6.2	5.6	6.2	5.7	6.3	5.7
Electromechanics	3.0	3.1	3.2	3.3	3.2	3.3	3.4	3.3	3.2	3.5

Fig. 4 Typical platform release map

once the players get familiar with the decision making the decision round time reduces from 15 to a couple of minutes.

Simulation workshops are started with motivation and virtual business presentations. The actual simulation begins with platform release selection. A typical release selection map is illustrated in fig. 4.

The non colored releases in fig. 4 represent low-risk strategy from the time point of view. The programs, which have selected late, darker colored releases, have taken a time risk, but may be rewarded with lower BOM–cost or better content of the building blocks.

After selecting the building blocks the participants start managing their programs. Each program team must decide right resourcing for various program tasks and quote their resource needs from common resource pool. This pool is typically tuned to be insufficient for all the needs causing a *pipeline overflow* situation, where steering group's role as decision maker will become relevant. Steering group can change business targets, prioritize program needs, terminate less profitable programs etc.

In this example program *Beta* has selected risky Engine and SW platform releases. The consequences of these selections can be seen on *completeness graph* (see fig. 5).

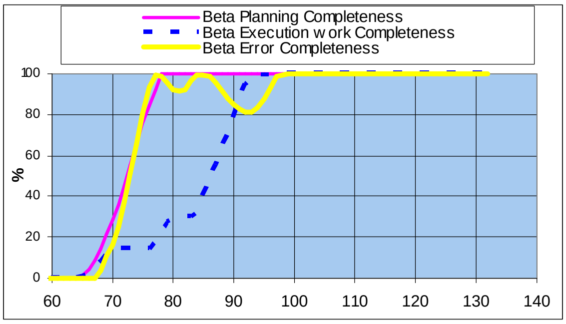

Fig. 5 Beta program completeness graph

Product design and integration work (dotted line) is not progressing well due to missing building blocks. At first, the late SW release is delaying the work until week 76 and later, the risky Engine release is holding the progress until week 84. Error correction curve seems to progress too early the reason being simply non-detected or non-existing errors due to slow integration work progress!

However, this was not due to inadequate execution work allocation (see fig. 6 dotted line). There are, as seen between weeks 70-80 ca. 20 workers, but in vain. The program team had even tried to use simultaneous overtime in order to boost execution work. In fact, they are only boosting program expenses.

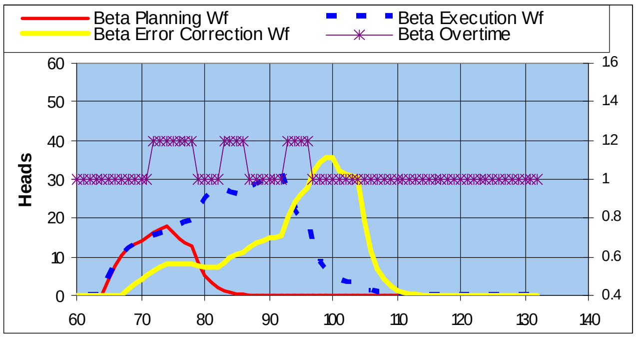

Fig. 6 Beta workforce allocations

This time the risks were rewarded with mature content of the late releases and product could be launched in time at week 104. What if there had been more delays or problems with the Engine release?

At the end of the workshop a couple of sample programs are being discussed and analyzed using *program business case* calculations and additional run-time data not given to the players during the game. Business results will also be considered on portfolio level, steering group behavior is discussed and the results are compared with autopilot and earlier simulation benchmarks.

Anyway, there have never been two similar workshops so far. In each workshop the situations and decisions have been different resulting with worse or better business results.

3 Realization of multi-project business simulator

3.1 Game version of the model

The game version of the model was constructed to be both versatile and flexible. Any number of the players can be replaced by autopilot and the model can be simulated without any physical players. A Microsoft® Excel user interface operates the run time version of the model enabling the end user to quickly modify the user interface and to add calculations, tables and graphs at moments notice. The player inputs and outputs can be delivered on paper or electronically (e.g. WLAN, html reports and decision input interface).

3.2 Description of the concept

Product players are given a task to produce a product with a given mission and functional specifications under given limitations. They design the product and after the concept is approved by portfolio players they start managing the product program and they are accountable to the steering group throughout the simulation. Steering group manages the entire portfolio consisting of several products with different missions. There are different parameter tuning sets forming different scenarios and different difficulty levels as well as sudden unplanned events which require immediate action from the players – these are controlled by the simulation leader.

3.3 The Simulation interface

The Simulation interface in Excel is designed for three different user groups: simulation designer, simulation facilitator and player.

Simulation designer has access to protected, hidden views and he can design new reports, buttons and such. Simulation facilitator is responsible for the run of the simulator during a simulation workshop, he will, among other things, initiate the simulation, print reports, collect decisions, to name but a few. He has also access to super user controls and during the simulation he can initiate different events and change the tuning parameters of the model creating different scenarios. The Simulation player utilizes a very simple interface for making resourcing decisions.

The player can have either access to electronic reports and decision interface with a laptop or all communication can also be handled with paper reports and written decisions delivered to the simulation facilitator in paper. In typical simulations, the reports are printed on paper and decisions made electronically.

3.4 Agile and innovative simulator project

The project was carried out on a very tight schedule: 5 months from the start to constant delivery of the workshops. The project work was also innovative: Due to tight project schedule the project work was intensive and highly interactive. The initial concept was maturing step by step while the model details were designed. The designers had to make fast decisions and also reject some of the original details during the design phase. Actually, the best features of the final simulation were invented during the first tests. However, the selected model architecture has proven to be solid and enabled the users to model highly complex behavior without substantial difficulties.

Further innovations have been made during the implementation phase without altering the original model. For instance the role and importance of steering group has grown into being now equal with product programs. Steering group is responsible for the whole product portfolio and we experience often confrontation with individual programs. This evolution of the simulation is based on constructive user feedback. There is still a lot of potential to enhance the features of the simulation sessions without touching the model itself.

4 Implementation experiences

4.1 Statistics

The implementation and frequent workshops using PPDS have started in June 2006 and this activity is currently taking place. By the end of June 2007 total 23 simulation workshops has been accomplished with total of 337 participants.

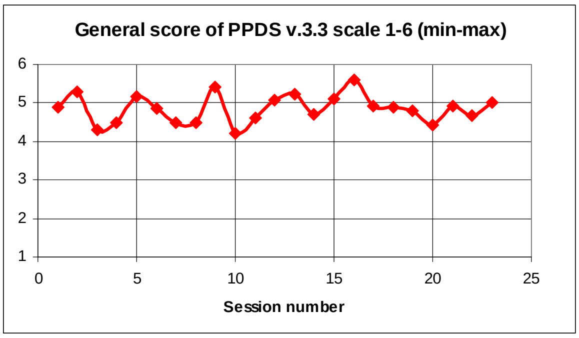

Fig. 6 General score of the simulation workshops

The feedback of the workshops has overrun the expectations. The *general score* of *the workshop* has been measured with scale 1 – 6 (min- max). The average calculated from the feedback forms is 4.85 for all workshops and 4.96 for the workshops held during 2007. The variation of the general score workshop by workshop is shown in Fig. 6.

Also written free form quotations of the feedback have been very favorable: "Thank you for yesterday's training, I was participating with product Gamma and I found the training extremely well designed, congratulations", "It was a pleasure to participate in such a comprehensive training – and fun!", "Best business simulation I have participated!" [10].

4.2 Robustness

The simulation solution has proven to be very robust in practice. The Vensim model has never jammed during the workshops and the only minor problems we have had are manual input keying errors by the facilitators causing recoverable error messages e.g. using comma instead of dot as decimal symbol when keying the input data. In later versions of the solution these have been eliminated by using web-based input sheet where wrong formats have been filtered before entering the simulation engine.

4.3 Autopilot

The autopilot feature of the solution increases the flexibility of the simulator. Maximum of 10 product programs can be simulated at the same time enabling easily over 40 participants to attend one workshop using 10 x 4 member program teams and 4 member steering group. However, a workshop can be successfully carried out with only 5 members without losing the interest of the business portfolio simulation. This is possible by using 4 one member programs plus 1 steering group member while the other 6 programs are running in *autopilot* mode.

Autopilot is a feature, in which the model calculates the decisions according to given criteria to act like an experienced participant's performance. This feature could be used for an optimized run of the simulation.

Autopilot has also been used as a benchmark runs for simulating the several tuning variants we have used. The participants will compete not only a program to program competition, but also portfolio vs. autopilot vs. earlier workshops with the same version. This has been increasing the interest of the participant teams to win their colleagues in this business simulation, where the end result can be accurately evaluated with the financial results of the simulated business. Several teams have achieved better results than the autopilot benchmark.

4.4 Research

The simulation approach enables also other forms of benefits e.g. metrics research, operational model development support and a reference platform to test information architecture changes. So far, these options have been studied to a lesser degree. A metrics research version of the simulator has been created, but its contribution to metrics development has remained pretty indirect. The indirect impact of the simulation workshops has anyway opened many participants' eyes to measuring program progress through dynamic S-curves and other parameters than used traditionally in company program reports.

Operational model development support and information architecture research is emerging. The new model enhancements and models being developed aim to tackle also these topics. The experiences of the current simulator have created credibility to use dynamic simulation to study the product process information logistics. With the aid of the simulation tools it is easy to create scenarios of information flow, feedback loops and consider the overall performance of the alternatives. This can be seen as a strong tool to support the operative process development and decision making.

In the earliest vision of the simulator development we planned to create a version for quantitative analysis. Although the current model consists of illustrative products and programs the numeric values are pretty close to reality. According to participant feedback the average score for "simulation reflects true behavior of company product development" is 4.58 and "simulation reflects operative decision challenges of our business" is 4.64 (1-6 scale). During the recent development work we have found out that quantitative simulation of the whole product process of the corporation would be too challenging. Therefore, our plans for quantitative analysis will have more limited scope and focus.

4.5 Other benefits

The workshop is also fun. Successes and fails raise emotions and cheering is allowed as seen on fig. 7.

Fig. 7 Simulation can be fun and rewarding

The simulation participants have experienced causes and effects of their decisions with average of 4.63 (1-6 scale). This has been one of the most important targets of the simulation workshop set up.

Some participants have attended two workshops, once as a program team member and the second time as steering group member, and experienced different challenges in decisions making. "Challenges were totally different from the other game" have the most of them said [10]. And it is so true and eye-opening to see how different drivers impact to decisions when having a role in single program vs. managing the portfolio of several programs. This mental learning is supported in the debrief stage where steering group decision behavior and argumentation of decisions is discussed. For example, terminating of a product program feel always more or less unfair from the program people point of view, but may be necessary decision for maximizing the company output, and profits.

The 3-4 hour workshops are very intensive, which can be seen in fig 8 where one steering group is fully devoted to maximize the profits of the company.

Fig.8 Intensive work of Steering Group members

In the feedback we have also asked for improvement ideas, out of which many have been already realized in later versions of the simulator. Additionally, many feedbacks have proposed significant enhancements of target audience and scope of the simulation. This proves for one part that the use of *management flight simulators* is not only useful as demonstrated, but expanding the scope and implementation is desired.

5 Future plans

The model has been continuously tuned and updated and the game version of the model will be used increasingly as a training tool in future.

The scope of the basic model is mainly limited to operational level and currently there are development projects going on to extend the model both horizontally (other operational models linked to the original) and vertically (models with scope on tactic and strategic levels).

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