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Business-oriented process improvement: practices and experiences at Thales Naval The Netherlands (TNNL)

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Abstract

Over the last decade many organizations are increasingly concerned with the improvement of their hardware/software development processes. The Capability Maturity Model and ISO9001 are well-known approaches that are applied in these initiatives. However, one of the major bottlenecks to the success of process improvement is the lack of business goal orientation. Additionally, business-oriented improvement approaches often show a lack of process orientation. This paper reports on a process improvement initiative at Thales Naval Netherlands that attempts to combine the best of both worlds, i.e. process improvement and business goal orientation. Main factors in this approach are goal decomposition and the implementation of goal-oriented measurement on three organizational levels, i.e. the business, the process and the team level.

Keywords: Process improvement; Business goal decomposition; Measurement

1. Introduction, background and approach

Thales Naval Netherlands (TNNL) creates high-tech defence solutions for naval and ground based environments. This paper addresses a process improvement initiative in the business unit Radar and Sensors (R&S) that started in 2002. This business unit has an extensive expertise in the fields of radar, infrared, weapon control, display technology and communications equipment. Products that are being developed and manufactured here can be typed as software intensive systems (embedded systems).

A pre-assessment of the quality management system for the overall hardware/software production creation process, on the basis of the new ISO9001:2000 standard, showed that the quality system did not meet the new ISO requirements. Shortcomings were identified from different ISO9001:2000 viewpoints, respectively:

- Restricted business orientation of quality management and business process improvement.
- Lack of control loops.
- No structured feedback mechanisms for continuous improvement (i.e. closing the control loops).

Confronted with the new ISO-requirements and the actual shortcomings, the organization decided for a redesign of its quality management approach and business improvement program. This paper reports on an improvement initiative that has been carried out. Both the steps that have been made and the main results gained will be presented.

The problems identified at TTNL can all be related to the lack of a comprehensive goal and process improvement-oriented control mechanism. This means that the theoretical background for this research can be found in the areas of process improvement and goal orientation. Each of these areas will be discussed briefly.

1.1. Ad process improvement

The two improvement approaches that have been applied, already for a period of 10 years at TNNL, are

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respectively: ISO9001, as developed by the International Organization for Standardization [6], and the Capability Maturity Model (CMM) as developed by the Software Engineering Institute [11]. ISO9001 is related to business processes and specifies the minimal requirements for a quality system. This standard has been applied at TNNL to develop a quality management system for the overall hardware/software production creation process. CMM addresses explicitly concepts for software process improvement. CMM has been applied at TNNL, in particular in software development departments. One department in the R&S business unit reached the CMM level 3 (out of five levels, of that level 1 is the lowest and level five is the highest). This means that a reasonable level of maturity has been reached in terms of the formality and the structuredness of the processes.

Both approaches, ISO9001 and CMM, can be considered to have complementary philosophies regarding quality and process management [10]. However, integration or combination of the two approaches is not easy because of the differences in business orientation, i.e. business processes in general versus software development processes. Regarding improvement, ISO9001 can be considered to have an open 'loop control'. This means that the actions in a business system are independent of the control system output, i.e. there is no explicit feedback mechanism used for the tuning of actions against well-formulated business goals. In CMM, improvement is based on the application of metrics to modify actions [4]. Although, CMM prescribes different types of processes and the application of metrics in process improvement, it lacks well-defined improvement goals on a business level. In fact, CMM's software process improvement has no starting or anchor points in business goal decomposition, from the strategic level towards the lower operational process levels.

Summarizing, it can be stated that both ISO9001 and CMM have a strong emphasis on business processes and measurement. However, both approaches are strongly restricted regarding the *motivation* of process improvement activities. In other words: these approaches are missing well-defined business goals as anchor points for process improvement. Summarizing, we can conclude that these approaches have a serious lack of business goal orientation.

1.2. Ad goal orientation

From literature, several 'goal-oriented' approaches for business improvement have been investigated. In Ref. [10], a formalized model is presented for linking different types of objectives in an organization, i.e. fundamental objectives, process objectives and functional objectives. Although a basis is given for the identification and decomposition of objectives, a direct link with (the control of) business processes is not elaborated. Two other well-known approaches are respectively, Six-Sigma [5] and Balanced Scorecard (BSC) [7]. Both approaches offer frameworks for business improvement. Six Sigma focuses at the improvement of customer satisfaction through defect elimination and prevention. Project selection and tracking focus on maximizing the benefits delivered to the business. Project success is measured in financial terms. Central in the BSC approach is a measurement system that prescribes the usage of pre-defined quantitative metrics from four business goal domains, respectively: financial, customers, internal business process and learning and growth. Companies should measure in order to 'balance' the business from a financial perspective.

The improvement approaches in the foregoing start from business goal definition and goal decomposition and are oriented on quantitative performance measurement. They offer frameworks for improvement, starting from business strategy, pre-defined types of business goals and pre-defined type of metrics. However, the link with the operational processes is missing. The emphasis in these approaches is much more on goal-oriented assessment of the various business domains of a company than on metric-based improvement of the operational product creation processes. Summarized, we came to the conclusion that these approaches had a serious lack of process improvement orientation.

We can conclude from these brief surveys that, although the individual activities are well researched, in literature little support can be found for the problem area identified at TNNL, that of explicitly linking process improvement to a business goal-oriented control mechanism. This paper tries to contribute to this perceived problem area.

Taking into account the identified shortcomings of the TNNL quality approaches, i.e. the restricted business goal orientation, and the investigated state-of-the-art improvement approaches, i.e. the restricted process improvement orientation, a new improvement initiative at TNNL was launched. This initiative is aimed at ensuring a link between business strategy and improvement of the product creation process. Main issues in this process improvement initiative are respectively:

- A stepwise decomposition of the overall business goals (not restricted to one particular business aspect, such as finance).
- A definition of organization-specific metrics (both qualitative and quantitative).
- The interrelations between on the one hand goals and metrics, and on the other hand business processes.

Regarding these three issues, the concept of 'closed loop control' is adopted and this concept was elaborated in the context of ISO9001:2000. The 'closed loop' concept, i.e. its explicit feedback mechanism, implies the definition of business goals and the application of business process measurement. Regarding measurement, an approach that has been used already for a number of years in software development environments is Goal Question Metric (GQM)

[8,9]. GQM supports answering questions such as: how to decide what needs to be measured, when should this be measured and where in the product creation process? In this way, an ad-hoc and unsystematic application of metrics and the collection of irrelevant data is avoided. In order to get grip on the measurement problem, two important assumptions respectively are (a) a metrics program should not be 'metrics based' but 'goal based' and (b) the definition of goals and measures need to be tailored to the individual organization. In particular the latter assumption was of interest at TNNL in order to link the business improvement initiative to the business strategy.

The approach that has been chosen to develop and implement the improvement project is a combination of a well-founded case study and empirical research. TNNL management definitely wanted an approach that started from specific characteristics of their business system, e.g. the way they had defined business strategy, the way they looked at improvement, the way business processes had been specified and the needs they had regarding the definition of performance indicators and metrics.

It was decided that first there would be a focus on (re)modelling the business processes. Formal process models were considered to be necessary on the one hand to establish a concrete context for business goal formulation on the strategic level, and on the other hand to identify business problems on a process and/or a team level. The specification of the process models would be based on an investigation of existing (and up-to-date) process documents at TNNL and on interviews with process owners.

Subsequently, a framework for improvement will have to be established that integrates the improvement activities on the different organizational levels, respectively, the strategic, the tactical and the operational level. This framework is needed to create a coherent overview on all the improvement aspects. For example, on each of the organizational levels, improvement goals and metrics will be defined with their interrelations within and between the levels. The development of the upper level of the improvement framework will be the result of a brainstorm session in that the top-management, some representatives of the process owners and the researchers participate. Regarding the definition of the process and team improvement goals, and the metrics, several workshops will have to be organized that will be moderated by a main process owner in close cooperation with one researcher.

Finally, the development of automated tools had to be planned, in order to be able to manage all the data that are going to be produced, collected, stored, and analyzed.

The structure of the paper is as follows. Section 2 introduces respectively: the business processes at TNNL, the identified problems and the directions for solution as formulated by the TNNL management. Section 3 presents a framework that acts as a basis of reference for the improvement initiative. Section 4 elaborates on the framework and addresses goal decomposition and the development of goal-oriented measurement in the process improvement initiative. Examples from practice clarify the approach that has been followed. Section 5 addresses the web-based tool support for the improvement initiative. Section 6 finalises the paper with conclusions, lessons learned and directions for future work.

2. Business processes at TNNL: practices, problems and solutions

In the product creation process at TNNL two main primary process chains can be distinguished. Chain 1 reflects the development of new and derivative products. Chain 2 describes the development of repeat products. In chain 1 the processes, in particular requirements analysis and design, are strongly driven by specific customer requirements. In chain 2 the processes are driven by the characteristics of existing product components. Both process chains are facilitated by a number of supporting process areas. For these areas, departments have been set up to support operational teams in the product creation process. Examples are a Configuration Management, a Data Management, and a Human Resource department. Furthermore outsourcing is supported explicitly. Because the main focus in the improvement initiative was on the two primary process chains, these are presented in Table 1.

2.1. Processes in practice: the chains

Both chains consist of a number of related processes that will be described briefly.

Chain 1. The most important chain 1 processes are depicted in Fig. 1. We can distinguish Proposal, Contracting, System Requirements Analysis, System Design, Product Development-Integration-Verification and Validation, System Integration-Verification and Validation, and Warranty. Each of these processes will be described in the following.

Proposal and Contracting (P&C). This process consists of activities such as the intake of a request, i.e. the translation of requirements into a proposal, the tuning with the product portfolio, the response to the customer, and negotiation tasks.

System Requirement Analysis and System Design (SRA/SD). In the analysis part of this process the customer requirements are translated into a system concept that is the basis for a complete system requirements specification. The system concept is validated with the various stakeholders in the development process. In this process also a feasibly estimate is established. The system design part of the SRA/SD process refines the system concept, based on the availability of building blocks and well-founded make or buy decisions.

Product Development, Integration, Verification and Validation (PDIVV). This process realises the system

Table 1
Problems and associated improvement actions

Problem	Improvement action
There is a lack of insight in the critical parts of business processes. This is in particular caused by the absence of a clear link between primary processes and the business strategy	The management at TNNL decided to introduce goal decomposition starting at the level of business strategy down to the level of primary processes and operational teams. In the improvement initiative only those processes, and their interrelations, will be addressed that contribute explicitly to the business strategy, see Ref. [1]
Continuous improvement, i.e. the specification, execution and control of improvement activities, is insufficiently addressed. In fact the emphasis in the current quality management system is on the specification of procedures for operational processes	It has been decided that feedback and control loops will be developed and implemented to establish continuous improvement. These continuous improvement loops will be based on quantitative measurement. Implementation of continuous improvement into the business processes will be supported by the application of intranet-based tools, e.g. regarding the definition of metrics, the collection and analysis of data, and the definition of improvement activities, see Ref. [2]
Developing and implementing an improvement initiative is a process of organizational change. Until now the employees have not been involved sufficiently in the process of quality management	The management decided to carefully plan and control the new improvement initiative. The entire organization should understand the importance of continuous improvement. Therefore awareness on the importance of process improvement should be raised and operational teams should play a central role in the determination of their own improvement goals, which have to be derived from business and process improvement goals, see Ref. [12]

according to the agreed specifications, assigns the work to be done to the production department or subcontractors and delivers the system components.

System Integration, Verification and Validation (SIVV). In this process the components are integrated. The final product is verified and validated against the original customer and system requirements.

Warranty. Regarding the warranty period of a product, activities are specified for system acceptation, receiving customer complaints on product failure, investigating defects and repairing defects.

Chain 2. The chain 2 processes describe the product creation activities of repeat products (Fig. 2). The Proposal, Contracting, and Warranty processes in this Chain are identical to those in Chain 1 and need no further introduction. The remaining processes are described below.

Engineering, Integration and Verification, Production. In these processes activities are carried out such as the determination of changes that have to be made to an existing product and of the validation of these changes. If reengineering is required of some parts of a product several sub processes or activities of chain 1 (mainly from the processes SRA/SD, PDIVV, SIVV) can be applied.

2.2. Problems and directions for improvement

In 2001 an independent quality assessment at TNNL based on the ISO9001: 2000 standard was carried out. In this assessment, the two primary process chains have been investigated together with the facilitating areas. ISO9001: 2000 in particular emphasizes, in comparison with the previous ISO9001 standard:

- Business processes should be the basis for quality management. In particular those processes should be addressed in a quality management system, that are of critical importance for the business system as a whole;
- A quality management system explicitly focussed on continuous improvement, as opposed to the more static view of the previous standard;
- This continuous improvement should be (visibly) based on formal measurement;
- Management should be explicitly involved in the design and implementation of the quality management system.

The assessment results were summarized in three major problems. For each of the problems, the TNNL management defined a direction for improvement. The result is depicted below.

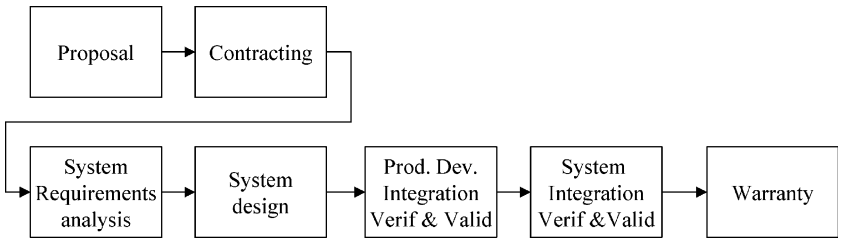

Fig. 1. Chain 1: development of new and derivative products.

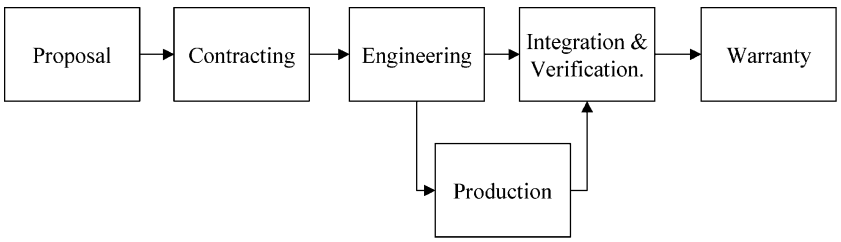

Fig. 2. Chain 2: development of repeat products.

2.3. A framework for the improvement initiative

Starting from the defined directions for improvement a framework has been developed to support the improvement initiative, see Fig. 3.

In this pyramid three management levels are recognized to link the improvement initiative to the business strategies, respectively, the strategic, the tactical, and the operational level [1].

The Strategic Plan is positioned in the strategic top layer of the pyramid and acts as a basis for both a Process Management System (PMS) and a Quality Management System (QMS). In this plan management issues are addressed such as:

- The long-term vision of the management,
- The mission statement, and
- Organisational development issues.

The PMS secures the product creation process. On the tactical level, the product creation processes are described according to the two process chains (chain 1 for new products and chain 2 for repeat products). The processes are described by means of a format with guidelines regarding, respectively: the description of the stakeholders of a process (such as the customer, the supplier, the owner), the process flow aspects (such as input, activities, output), and the performance of a process (such as process goals, improvement actions and metrics). For all processes a general description and detailed information (e.g. action lists) are available. On the operational level also supporting information is available such as checklists, templates, guidelines and best practices.

The QMS supports in particular the continuous (quality) improvement of the product creation process. Continuous quality improvement is based on goal decomposition, i.e. from business goals on the strategic level to process improvement and team improvement goals on the operational level. Regarding quality management, the Quality Plan and the so-called 'cockpit' are important concepts.

The Quality Plan, on the tactical level of the framework, forms a basis for the determination of improvement goals. The Quality Plan starts from the business strategy and specifies respectively, the actual vision on continuous improvement, the short-term improvement goals and the accompanying improvement actions.

The progress of the improvement program is monitored on the basis of performance indicators in the so-called management cockpit. The cockpit will be addressed in more detail in Section 4. Cockpit review by the management team takes place monthly. The Quality Plan is subject to management review at least twice a year.

3. Towards goal-oriented improvement

The pyramid framework acts as a reference for the development and implementation of the improvement initiative. To develop the improvement initiative three important principles were taken from results of recent research in the domain of business improvement, respectively:

- Goal decomposition. business goals should be derived from overall business strategy. Based on these business goals operational process and team improvement goals have to be defined [1,3,10]. Both for business goals and for process improvement and team improvement goals, improvement actions have to be defined.
- Metric-based improvement. Management and control of an improvement programme should be based on measurement. For each business goal, process improvement goal and team improvement goal a (set of) metric(s) has to be defined to be able to quantitatively control the effectiveness of improvement actions [13,15].

Fig. 3. A framework for the improvement initiative.

- The decomposition of business goals into process improvement goals and team improvement goals, and the definition of metrics should be based on the needs and the requirements of the operational teams, which can be considered to be the main stake-holders in the primary business processes [12,14].

In accordance with these principles, the improvement initiative was reformulated as a goal-oriented improvement initiative.

3.1. Goal-oriented improvement in the business model of TNNL

Starting from the pyramid framework, the goal orientation in the improvement initiative has been elaborated into a high-level business model, see Fig. 4.

In this business model, the PMS is depicted as a horizontal dimension that reflects the transformation of materials and sub-products into products via process chains. It is aimed at maintaining operational control. The vertical dimension addresses the QMS, and is aimed at continuous improvement of the operational business processes. As stated before, in the horizontal PMS the operational processes and their interfaces are specified, authorities and responsibilities are defined, business rules e.g. for delivery on time are specified, etc. In the vertical dimension the improvement of processes and sub-processes has to be managed (the QMS).

In order to link the business strategy (the vision and the mission statements of the management) to the product creation process, the business strategy is refined in terms of business goals and associated sub-goals. Subsequently process improvement and team improvement goals are derived. Based on this goal decomposition, improvement actions are defined both on the business level, the process level and the team level of the business model.

To plan and control continuous improvement in the business model the plan–do–check–act cycle concept is implemented on the different levels of the goal hierarchy. For the sake of clarity of Fig. 4 the plan–do–check–act cycle is only drawn in this figure on the lower level of the model. Of course the feedback mechanisms should also include feedback about the quality of the higher-level process improvement goals, and the lower-level processes should also report on the quality of the higher-level business goals. To control the effectiveness of the improvement actions their efficiency and adequacy has to be measured. On the strategic level the business strategy is defined. On the tactical level business goals and performance indicators are defined which are derived from the business strategy. For each business goal one or more metrics are defined. Subsequently the business goals are decomposed into process improvement and team improvement goals. Also for these process and team improvement goals, metrics are to be defined.

The decomposition of business strategy and business goals into process and team goals, and the definition of accompanying metrics is not a straightforward, formal or deterministic process. Consensus building and inter-subjective decision-making is central. Therefore relevant stakeholders have to be involved in this process of goal decomposition, improvement action definition and metric determination. Stakeholders are parties that play a direct

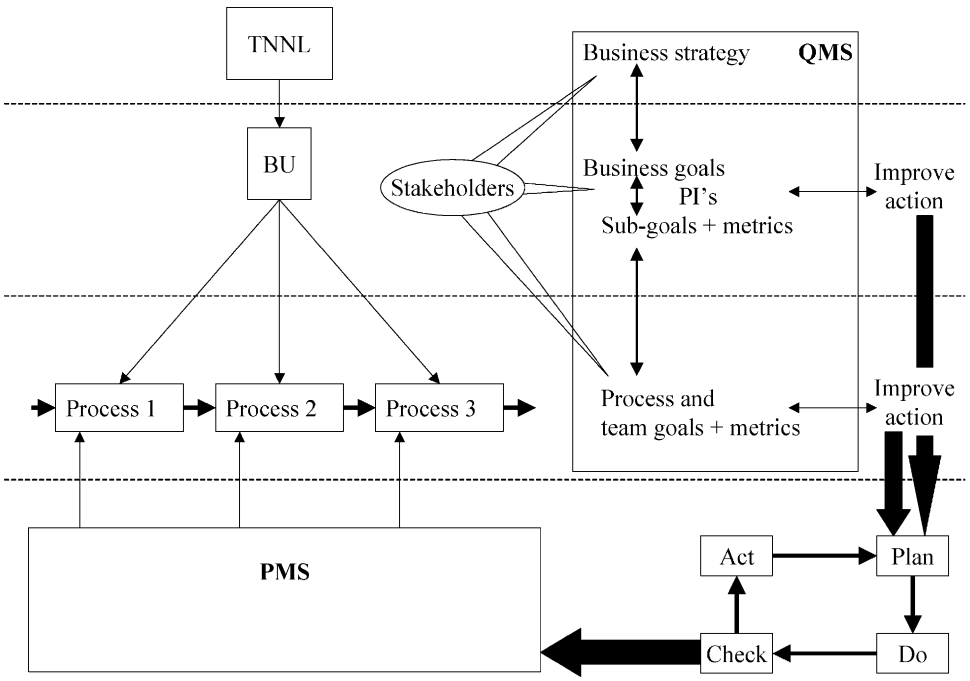

Fig. 4. Goal orientation in the improvement initiative.

or indirect role in the product creation process. They can be both operational teams that develop the products, external customers, internal customers who use the output or deliver the input to a process. To organise this stakeholder involvement, workshops, brainstorm meetings and training sessions have to be planned carefully.

In Section 4, the development of this goal-oriented improvement concept at TNNL will be presented. Here, concepts of goal decomposition and measurement play a central role. Regarding the involvement of stakeholders, we will focus on the operational teams that execute the actual process improvement goal decomposition, the team improvement goal definition and the metrics determination.

4. Development of goal-oriented business improvement at TNNL

This section presents the approach that was followed and the (intermediate) results that were reached. Three phases can be recognized:

- A phase where top management define the strategy, the business goals and sub-goals, the performance indicators and the metrics, see the upper layers of Quality Management in Fig. 4.
- A second phase in that the process improvement goals and the accompanying metrics are defined, see the lower layer of Quality Management in Fig. 4, and
- A third phase in that the team improvement goals and metrics are defined, see also the lower layer of Quality Management in Fig. 4.

In Section 4.1 for the first phase only the results of the management discussions and the decisions that were made are reported. In fact this was a 'black box' strategic management process where only the outcome can be presented. Section 4.2 reports on a procedure that has been developed for process improvement definition and gives some examples of process improvement goals and metrics that have been defined. In Section 4.3, the process of the definition of team improvement goals and metrics is described. This process is also clarified with practical examples.

4.1. Phase 1: business strategy, objectives and performance indicators

The high level management has defined five strategic objectives in the Management Handbook. These statements are based on the strategic objectives of TNNL and are taken as starting points for the development of the improvement initiative within the particular business unit R& S/JRS. The strategic objectives are respectively:

Table 2
Strategic objectives and their interpretation at the business level

Objective	Interpretation
Adequate profitability	To be reached via an efficient and effective executed creation process
Delivering customer-oriented solutions	Emphasis on meeting customer expectations and requirements (e.g. based on adaptability of products)
Being the employer of choice	Central is the stimulation, motivation, and improvement of the competencies of employees
Developing both existing and new markets	To be reached via maintenance and improvement of relations with internal and external customers
Adequate and efficient knowledge- and technology management	Maintenance and development of all competencies regarding product development, including requirements determination, analysis and design and verification and validation, as well as various management and support competencies

- Adequate profitability
- Delivering customer-oriented solutions
- Being the employer of choice
- Developing both existing and new markets
- Adequate and efficient knowledge- and technology management

These rather abstract objectives have been elaborated to make them more applicable on the tactical level or business level, see Table 2.

In order to measure whether or not these strategic objectives are met, management has identified five performance indicator areas (PIA's), see also Table 3.

These five performance indicator areas are displayed in a so-called management cockpit that acts as a control mechanism to keep track of the improvement results. The management cockpit will be addressed further in the rest of this section.

Strategic objectives and associated performance indicator areas act as guidelines. Using these, associated business goals and metrics can be derived. For each PIA a number of business improvement goals can be defined, see Table 4.

The metrics can be used to decide whether or not specific business improvement goals are reached, and subsequently what the score is of a particular PIA in the management cockpit at the strategic level. A distinction is made between

Table 3
The performance indicator areas at the business level

Efficient and effective executed creation process
Customer-oriented solutions
Employees
Customer satisfaction
Knowledge base

Table 4
Business goals per PIA

Efficient and effective product creation process
Decrease the costs of adapting product or building blocks to customer requirements
Improve the quality of the order intake forecast
Improve customer confidence in critical process interfaces
Improve reliability of product delivery
Improve budget discipline
Customer-oriented solutions
Improve customer requirements specification regarding the match with TNNL product characteristics
Decrease the costs to adapt product or building blocks to the customer requirements
Employees
Satisfied employee
Improve the allocation potential of employees
Improve the motivation of employees
Customer satisfaction
Satisfied internal customer
Satisfied external customer
Knowledge base
Establish a critical level of knowledge
Improve the added value of the knowledge base
Spend sufficient effort into the organization's level of knowledge

hard and soft metrics, or quantitative and qualitative measures. A hard metric gives formal figures (e.g. illness rate, due date performance and spending rate). Soft metrics express confidence or satisfaction (e.g. confidence that goods will be delivered in time, confidence that the quality of baselines in the product creation process are adequate, customer satisfaction and employer satisfaction). Usually both types of metric are required to provide sufficient information. Give in Table 5 are some examples of metrics

Table 5
Examples of goals and metrics

Example 1
Performance indicator area: efficient and effective product creation process
• Business goal: improve reliability of product delivery
• Metric: in-time delivery with respect to operation planning
• Norm: 80%
• Business goal: improve customer confidence in critical process interfaces
• Metric: appreciation score of the key stakeholders in the process, measurement based on questionnaire
• Norm: >7
Example 2
Performance indicator area: customer-oriented solutions
• Business goal: improve customer requirements specification (CRS) regarding the match with TNNL product characteristics
• Metric: number of adjustments of CRS required with respect to existing product portfolio characteristics
• Norm: <1.25*(reference data from experience base)/time
Example 3
Performance indicator area: employees
• Business goal: improve the motivation of employees
• Metric-1: staff turnover, norm: 5%
• Metric-2: Average number of overtime hours per employee
• Norm: $<$ *x*-h per person

for the PIA's Efficient and Effective Product Creation Process, Customer-oriented Solutions, and Employees.

Based on the application of the metrics, periodically the PIA-scores are being generated per performance indicator area (PIA) and shown in the management cockpit, as depicted in Fig. 5.

The PIA-scores that are presented in the management cockpit are used by the management to evaluate the strategic objectives. Subsequently the business goals act as starting points for improvements that have to be carried out on the process and the team level. In Section 4.2, the decomposition of the business goals into process improvement goals and the determination of accompanying metrics is presented.

4.2. Phase 2: decomposition of business improvement goals into process improvement goals and definition of metrics

Starting from the business goals, the areas in the product creation process have to be identified where specific (parts of the) processes should be improved These improvements are then defined as process improvement goals. Each goal at the process level has to be provided with one or more metrics.

The decomposition of the business goals into process improvement goals for the operational teams on the one hand and facilitating departments on the other hand is performed in the following steps:

1. Per process of the product creation process a small team of stakeholders in the process is formed.
2. Each team makes an inventory of the improvement needs of the process and translates these needs into process improvement goals.
3. The process improvement goals are linked with one or more business goals. Goals that cannot be linked with any business goal are rejected.
4. The remaining process improvement goals are subdivided into three classes:
   a. Process improvement goals that can be assigned to operational teams, which execute the process.
   b. Process improvement goals on the interface between processes.
   c. Process improvement goals to be assigned to the departments, which facilitate the operational teams.

In the following paragraphs, we will give some examples of the determination of process improvement goals. Because we restrict ourselves in this paper for the sake of clarity to the operational processes as stated in Section 1, we will address in these examples only process improvement goals of the processes themselves and process improvement goals at the interface of processes. The process that we will focus on in this example is the Product Development, Integration,

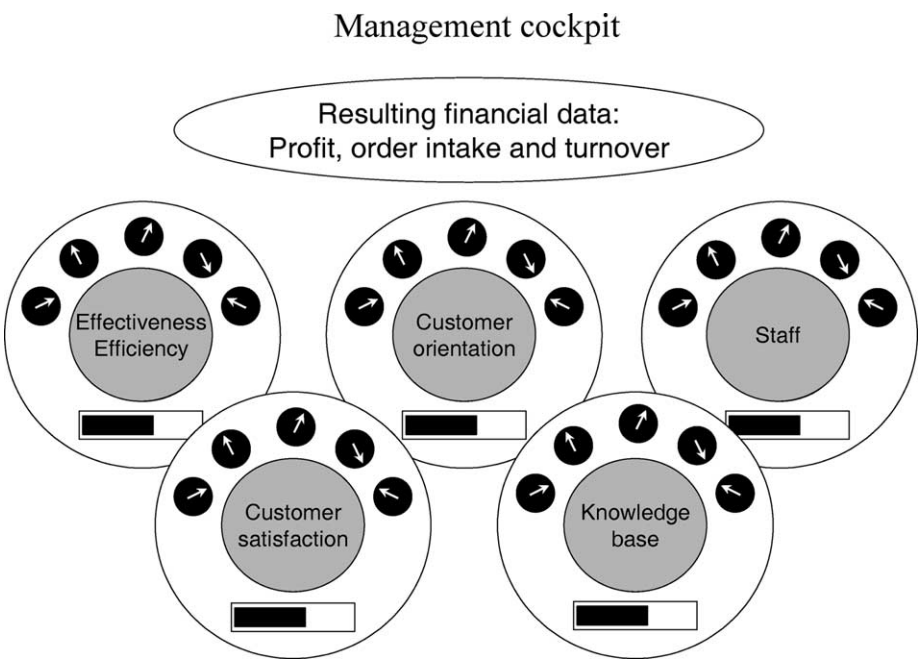

Fig. 5. The management cockpit.

Verification and Validation (PDIVV) process, see Fig. 1 in Section 2.1.

The PDIVV process and its stakeholders. The PDIVV process is a process in chain-1 that produces the system according to the agreed specifications, assigns the work to be done to the production department or subcontractors and delivers the system components, see Section 1. The PDIVV process has interfaces with the processes SRA/SD and SIVV, which are considered as the most important stakeholders, together with the PDIVV-employees. The output of the SRA/SD process, and the input of PDIVV, is a validated and complete system requirements specification that is based on the availability of building blocks within TNNL. The output of PDIVV, and the input for SIVV, is a produced system and/or components that have to be integrated into a final product in the SIVV process. The final product is verified and validated against the original customer and system requirements. In Table 6, we give examples of process improvement goals with respect to respectively, the operational teams, the SRA/SD interface and the SIVV interface.

4.3. Phase 3: the decomposition of process improvement goals into team goals and the definition of metrics

The decomposition of the strategic objectives via the business goals into process improvement goals and the definition of accompanying metrics form the basis for actual business improvement The improvement goals have to be embedded in the daily work of the operational teams. This section reports on the way workshops are carried out to determine team improvement goals and metrics. The team improvement goals and metrics are registered in the QMS and serve there as a basis of reference for the day-to-day work of the various operational teams.

Workshop objectives. The implementation of process improvement goals into the work of operational teams was supported by workshops. The objectives of the workshops for individual teams were to define its own set of team goals

Table 6
Examples of process improvement goals

Process improvement goals with respect to the operational teams executing the process
- Process improvement goal: executing the work in accordance with the project plan
  - Related business goal: efficient and effective product creation process (see Section 4.1)
  - Metric: procentual time delay ((t-real - t-plan)/t-real)
- Process improvement goal: constructive feedback on personal performance
  - Related business goal: improve the motivation of employees (see 4.1)
  - Metric: questionnaire to determine a score for employee satisfaction regarding their interaction with Resource Management

Process improvement goals with respect to the SRA/SD (interface at the input side)
- Process improvement goal: improve the stability of the system requirements specification
  - Related business goal: improve reliability of product delivery (see 4.1)
  - Metric: changes over a period of time in (#requirements to work on/#requirements total)

Process improvement goals with respect to the SIVV (interface at the output side)
- Process improvement goal: improve satisfaction of the SIVV employees on the quality of the output by increasing frequency of reviews
  - Related business goal: satisfied (internal) customer (see Section 4.1)
  - Metric: (effort/time needed to react to complaints from SIVV)/(effort/time needed for the development of the output)

on the basis of, on the one hand, the process improvement goals and, on the other hand, the teams own particular project objectives and the individual experiences of each team member. Team improvement goals can be related to one or more process improvement goals; just like process improvement goals can be related to one or more business goals.

Workshop design. The workshops are being designed carefully in accordance with the size of the teams, which varies between 6 and 25 persons. The approach is to reach agreement on team improvement goals via dialog and mutual understanding. For a workshop relevant process improvement goals are pre-selected and act as a basis of reference during the whole workshop. The starting questions of a workshop are respectively:

- 'How do we contribute as a team to specific process improvement goals of the department',
- 'How do we measure team contribution', and
- 'What are individual roles in that'?

Sub-groups of three to five persons are formed to discuss process improvement and team goals, both in parallel and sequential. They are provided with pre-defined templates that are based on the 'cockpit' and with the GQM paradigm [7]. Team members can participate in more than one (sequentially) operating subgroup. Several iterations are used to derive team improvement goals and metrics from process improvemet goals. The group's outcomes are reviewed each iteration by other sub-groups. Finally, based on consensus building, the most suitable team goals and metrics are selected, and an action plan is proposed. Based on the iterations, the review mechanisms and the changing groups, maximum use of the variety of a team is reached, creating a large cohesion within the operational team.

Workshop evolution. Over a period of 18 months, monthly follow-up sessions are organized. In these sessions experiences are collected regarding the fit of the process improvement goals with the team improvement goals and the application of the team improvement goals and the metrics in practice.

Preliminary workshop results. Some examples of the results of the workshops are:

- Explicit team improvement goal definition provides teams with a clear focus on the major topics of their work
- Increased awareness of the teams on the impact of their work on the business as a whole. It provided teams with a 'helicopter view' on their daily work.
- Clear contribution to the 'team spirit' of the employees.
- Redesign of particular activities in the team, e.g. improving the efficiency of the work
- Follow-up workshops showed that specific important improvement topics could be kept on the agenda and didn't tend to disappear due to the day-to-day worries.

Table 7
Examples of team improvement goals

Process improvement goal: improve satisfaction of the SIVV employees on the quality of the output by increasing frequency of reviews, see Section 4.2
- Team improvement goal: improve the quality of the specification
- Metric: objectiveness of the specification
- Norms:
  - $>$ 95% of the specification is described in quantitative terms
  - $>$ 95% of the essential specification is under control (determined on the basis of consensus of the team members)
  - $>$ 80% of non-essential requirements is under control (determined on the basis of consensus of the team members)

Experience issue: the distinction between essential and non-essential specifications supported the team members in getting a clear focus on main and side aspects of the specification
- Team improvement goal: improve communication with (internal) SIVV customers
- Metric: level of (internal) satisfaction, based on among others a number of contacts with internal customers and formal respons given to questions
- Norm: >6 (on a scale of 1 to 10)

Experience issue: the whole team was involved in the 'rating' and the team as a whole became aware of the number of contacts with the internal customers and the 'quality' of those contacts

Some examples of metrics. In Table 7, two examples are given of the determination of team improvement goals, metrics and norms, on the basis of the process improvement goals as defined in Section 4.2. For each of the examples a brief experience issue is given.

5. Tools to support the usage of team goals and metrics

An intranet-based tool supports the usage of both the QMS and the PMS at TNNL.

On the screen in Fig. 6, the top of the pyramid consists of the so-called Hand-Book that is in fact an operationalisation of the Strategic Plan of the company, see Fig. 3 in Section 2.3.

By clicking one of the two Chains, in the PMS part of the pyramid framework, the system provides the user with a particular process model. Subsequently each process in this process model can be clicked and for each process a description of the main aspects of that process is given in terms of activity, input and output, and interface specifications. Additional information on the control and execution of a process can be found on various tools and techniques such as checklists, guidelines, templates and lists of best practices. This additional information supports the user in the development of project plans, the generation of problem reports, etc. By clicking Norms and Standards, the system provides the user with TNNL-specific (technical) engineering rules, e.g. regarding the design of a particular hardware/software product. Also checklists can be found that act as guidance for particular activities, e.g. checklists for the execution of reviews during the product creation process.

In the QMS part of the pyramid framework, by clicking Cockpit, the system provides the user with a Cockpit-model

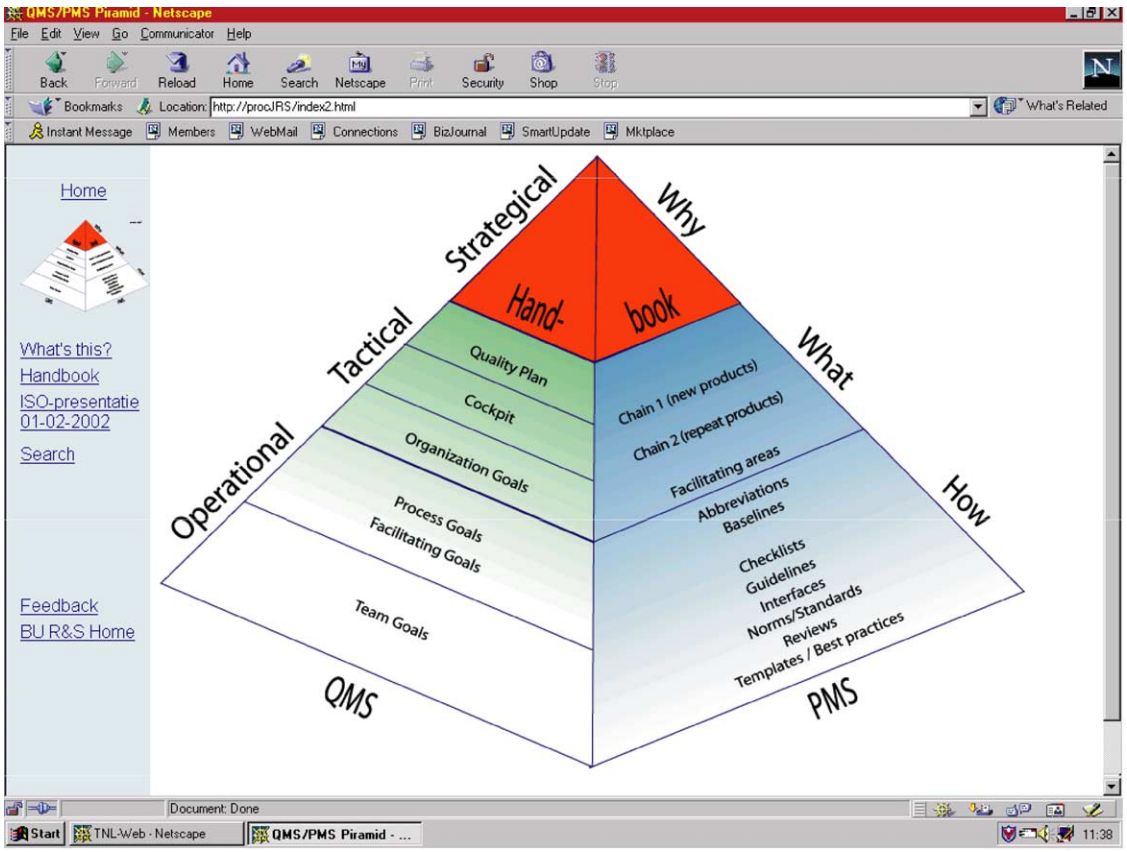

Fig. 6. Intranet-based tool support for the improvement initiative at TNNL.

that contains periodically updated Performance Indicator-scores, see Fig. 5 (Section 4.1) These scores are related to the strategic objectives of the company. Clicking on 'organizational goal', 'process goal', or 'team goal' provides the user with input/output screens such as depicted in Fig. 7.

On top of Fig. 7 a process (improvement) goal (in Dutch: Procesdoel) is shown of a particular process, i.e. the Engineering process of Chain 2. A few lines below also the business goal (in Dutch: Organisatiedoel) that is related to the process goal is reflected. For each process improvement goal, specific actions (in Dutch: Verbeter-actie) can be defined in the lower part of the screen. In the lower part, on the right in Fig. 7, metrics (in Dutch: Metriek) can be defined for each process improvement goal.

Based on regular input, i.e. goals, metrics, data, the various teams working in the two Chains can estimate and/or calculate the effectiveness of their improvement actions. Teams can compare their results with the results of other teams and teams can learn form the way other teams are dealing with process goal and metrics.

Periodically the data on progress and effectiveness of improvement actions at the process level are used by the higher management as input for the calculation of the PI-scores in the Cockpit.

Currently the first steps have been made on the usage of the web-based tool support. It will be clear that the company is still climbing a learning curve regarding the usage of this tool, the definition of metrics and the collection and analysis of data. However, the tool provides the TNNL-employees, on the various management levels, with an automated and integrated support for the implementation and the evolution of the improvement initiative at TNNL.

6. Conclusions and lessons learned

A pre-assessment on the basis of the ISO9001:2000 standard at TNNL showed shortcomings regarding quality management and continuous improvement. To improve the situation the management decided to set up an improvement initiative. This initiative had to based on 'the best from both worlds' in business improvement approaches, respectively metric-based process improvement and business goal decomposition. The *first lesson learned* in this project is that process improvement and business goal decomposition approaches can be combined successfully in practice. Based on a business improvement framework, three directions for solving the problems have been defined, i.e. goal decomposition, metrification and stake-holder involvement. Regarding improvement three levels

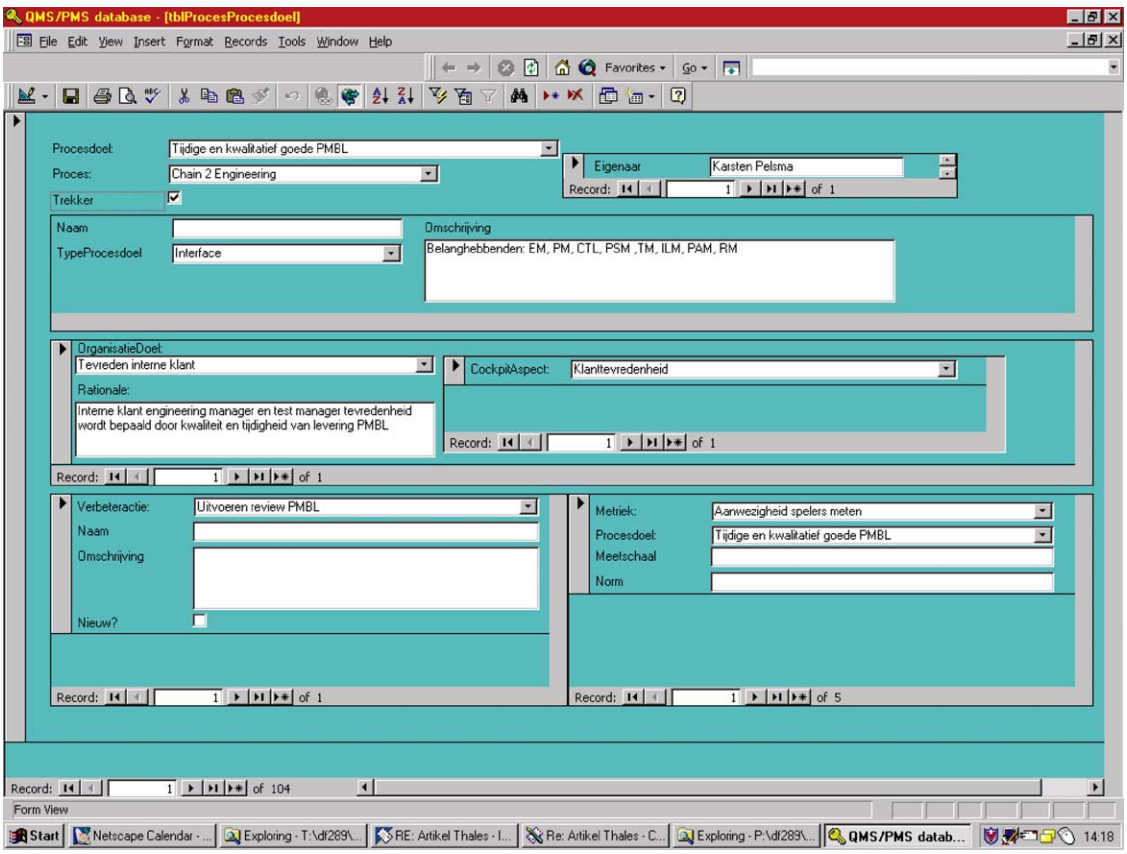

Fig. 7. Intranet-based tool support for process, team goal, and metric definition.

of improvement actions have been elaborated, respectively, the business level, the process improvement level and the team improvement level. On each of these levels appropriate stakeholders played a role in the determination of metrics, e.g. top management, project or process leaders, and operational team members.

From this the *second lesson learned* is that an explicit definition of improvement goals, provides stake-holders with a clear focus on the major topics of their managerial work and/or operational tasks. This contributes to a large extent to the definition of appropriate metrics, related to the improvement actions of the particular management levels. The metrics are ultimately used to determine the effectiveness of the improvement actions on a continuous basis. On the team level the team improvement goal definition and the determination of metrics is performed in workshops that are organized on a regular basis. Finally the evaluation of the improvement goals and the application of the metrics, e.g. the collection and the analysis of data, are supported by web-based intranet tools. From this we came to our *third lesson learned* that says that regarding business improvement a company has to climb a learning curve, in particular regarding the usage of automated tools, the definition of metrics and the collection and analysis of data. However well-founded automated tools can and should provide a company, on each of the distinct management levels, with integrated support for the implementation and the evolution of an improvement initiative.

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