KPI MEASUREMENT IN ENGINEERING DESIGN – A CASE STUDY

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ABSTRACT
As Engineering Design (ED) is typically carried out as a project [1], this paper proposes that standard Key Performance Indicators (KPIs) for project management are appropriate for measuring and monitoring ED processes. A case study was performed to study which KPIs can be used and how they need to be changed to fit specific ED projects. The study was undertaken in the context of a business transformation project at a global power generation equipment manufacturer during a period of 15 months in three locations. One major objective of the project was to develop a KPI reporting concept covering the design process in order to implement an interactive Management KPI Dashboard. The case study supports the view that standard project management KPIs can be used with some customizations specific to the nature and size of the company, the projects and the project teams.

Keywords: KPIs, case study, performance management

1 INTRODUCTION

1.1 General
What cannot be measured cannot be improved. This is a well known principle in both business and project management, which is reflected, for instance, in the PDCA (plan-do-check-act) methodology, where the intention of the 'check' step is to measure the success of the implemented process [2].
Traditionally, businesses usually measure their financial performance – in terms of e.g. turnover, earned value added (EVA), working capital (WC) and net profit (NP). Focusing on financial measures only, however, is not sufficient as other factors might be disregarded. In fact, the introduction of strategic performance measurement tools, such as Balanced Scorecards (BSC) has shifted the focus to other ways of measuring performance. BSCs are a *balanced* collection of financial and non-financial measures or key performance indicators (KPIs), usually less than 25, spread across 3 or four different perspectives, typically finance, environment, processes and strategy.
KPIs are quantifiable measurements that help an organization measure the success of critical factors. They should be agreed in advance, and depend on the organization's objectives. For example, for a university the number of students that finish on the scheduled time can be a critical measure, whereas for a service organization the level of customer satisfaction can be a more appropriate measure than the number of customers served. In general, KPIs are useful for decision-making and decision-rationalizing, coordination, and self-monitoring [3].

1.2 Implementation aspects
Information technology has become an integral aspect all major business processes. Consequently, all data necessary for measuring a KPI should be obtained from the same IT systems (i.e. same data base) that are used for executing the business process that needs to be measured, following a "single source of truth" philosophy.
Analyzing and processing this data falls into the domain of Business Intelligence (BI). Typical applications used on enterprise level are e.g. SAP BusinessWarehouse (BW) / BusinessObjects or InformationBuilders WebFOCUS or IBM Cognos BI.

However, from the authors' experience, there are three main IT-related problems regarding KPI measurement in practice:

1. **Heterogeneous application and data landscapes:** data is obtained from various, non-harmonized data sources and analyzed using different applications
2. **KPI inflation:** due to the little effort it can take to retrieve KPIs by means of BI, some companies use more than 100 metrics to manage (parts of) their business, losing overview of what these metrics mean and how they are related to each other – thus making no proper differentiation between an operational report and a key performance indicator. Very often, companies measure what they can measure – and not what they should measure.
3. **Pseudo-accuracy:** especially when the first two problems apply, the accuracy of the KPIs becomes questionable and also prone to deliberate "data massaging". These inaccuracies, however, can be difficult to recognize. If the recipients of the KPI reports do not suspect this, they may be lead to wrong business decisions. If they do, they may lose confidence in the KPIs, making the whole solution useless.

From a change management perspective, the implementation of KPIs should be done incrementally and accompanied by strong coaching and training. Reluctance to adapt and comply is often followed by fears of being constantly observed and evaluated, and the effect of implementing it to increase performance can be lost by the team's aversion to change and continuous evaluation

1.3 KPI measurement in project management

As every project is very different and fits differently onto the strategic map of an organization, the critical factors to be measured change from project to project. There is however agreement on a few principles for selecting KPIs for project management, which are related to time, budget and scope. To be useful, KPIs for project management should: a) include non financial measures; b) be measured frequently; c) be acted on by the CEO and senior management team; d) clearly indicate what actions are required by staff; e) be measures that tie responsibility down to a team; f) have significant impact and; g) encourage appropriate action [4].

1.4 KPI measurement in engineering design

There is very sparse literature on KPIs for Engineering Design (ED), perhaps because of the often non-determinate nature of this process. However, the performance of design teams should as well be measured, as the delivery needs to be within the requirements, on budget and on time. In fact, ED usually takes places

- as a unique process,
- consisting of a set of coordinated and controlled activities with start and finish dates,
- undertaken to achieve an objective conforming to specific requirements,
- including the constraints of time, cost and resources,

which is the definition of a project according to [5]. Gericke, for instance, acknowledges that "[...] project management as a concept is an integral element of the product development process." [6]. It therefore suggests itself to apply Project Management KPIs to ED.

2 CASE STUDY

2.1 Initial situation

The case study described in this paper took place at the Products Division of a global manufacturer of power generation equipment. The division is sub-divided into three business segments which represent the three Product Lines Gas Turbines, Steam Turbines and Generators.

Through a history of growth by mergers and acquisitions (cf. [7]) as well as several business reorganizations the business processes and IT system landscape had become extremely heterogeneous, so that a Division-wide business transformation project had been launched. The objective of this project was to

- identify and analyze the weak spots of the as-is processes,
- design harmonized to-be processes for all three business segments and to
- implement the new processes based on SAP,

thereby supporting the strategic targets set by the management of the Products Division illustrated in figure 1.

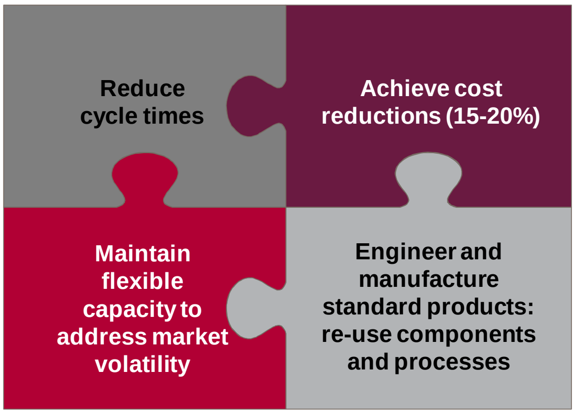

Figure 1. Strategic targets of the client's Product Division

The process scope of the transformation project included, but was not limited to Supply Chain Management, Finance, Manufacturing, Quality Management and Engineering (Design).
A central element of the to-be engineering, manufacturing and project planning processes were so-called functional components (FC): when a customer order is placed for e.g. a gas turbine, a work breakdown structure (WBS) of functional components is created (e.g. "rotor", "casing", etc.) from which the overall production schedule is derived (which, for a gas turbine, has a duration of about twelve months). In this schedule, each functional component is mapped to a fixed chain of activities: design engineering (D/E), production engineering (P/E), purchasing (PUR) and manufacturing (MAN). Based on planning templates, these activity chains are connected to each other, creating a planning network with start dates, end dates and dependencies of activity chains (see figure 2.).

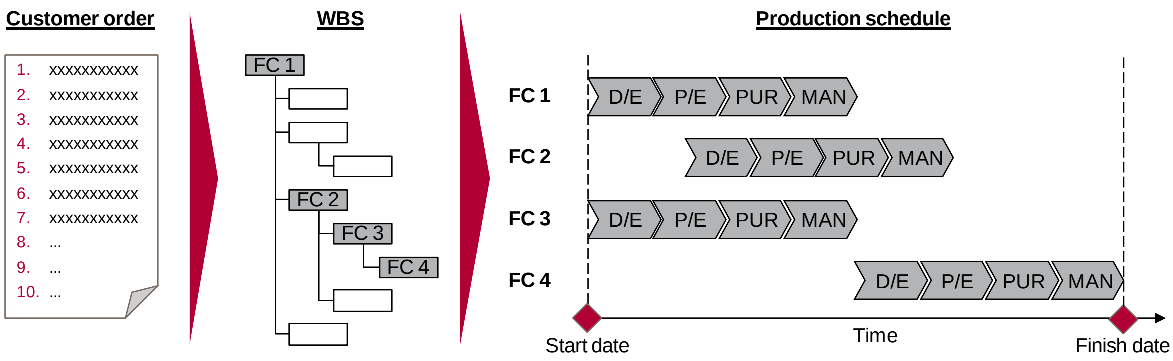

Figure 2. Connection between customer order, work breakdown structure (WBS) and production schedule

In accordance to the considerations in 1.1, one important objective of the transformation project was to develop a KPI reporting concept covering the above process scope in order to implement an interactive Management KPI Dashboard.
Originally being out of scope (partly for the reasons discussed in 1.4), management eventually realized the need to include ED KPIs in the reporting concept too.

2.2 Development of Engineering Design KPIs

Immediately after the decision to expand the scope of KPI reporting to Engineering, the project team, drafted an initial "long list" of 30 Engineering KPIs, incorporating input from selected company-internal subject matter experts as well as using KPIs from literature. Each KPI was described using a standardized form which contained the information shown in figure 3.

Engineering Productivity [redacted]

Objective	ID
To control the amount of customer-chargeable engineering hours to increase the number of projects in the engineering domain	117

Definition & Milestones
• Engineering productivity is the ratio between chargeable hours (to customer projects) and available hours (excluding contractor hours) • Chargeable hours are all hours booked to New App (A), Mods & Ups (B), Engineering Consulting (D), Quotation / Tendering (E) and First Time Spare parts (H) projects • Available hours are the total working hours of all engineers in the reporting period (contractors not included)

Recipient	BSC Category	Frequency	Unit	Responsible	Layout	Currently reported in
Plant	Process	monthly	%	Engineering	Historical bar chart	n/a

Data Objects	Data Basis / Selection Criteria
• HR mini master records • ID • Cost Center • Contractual Work hours • CATS (Cross Application Time Sheet) records • ID • Hours • Recipient • Date • Status	• HR → Cost Center: associated to EN • HR → ID = CATS → ID • CATS → Status = “Approved” • CATS → Recipient can be three different data objects: • CS Order: counts • PSP Element: only count when Project “Type = EN” and the identifier does not begin with “F” (= R&D) • Network Activity: lookup parent PSP Element; see above

Calculation
Total engineering hours booked against billable projects / Total contractual work hours * 100

Notes
• Clarification needed: should contractor hours be included in the calculation? • The Contractual Work hours are currently not part of the HR mini master records; interface to corporate HR systems ([redacted]) planned • Data privacy aspects must be taken into account (consult Works Council) • How to deal with vacation?

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Figure 3. Example of KPI description form (client confidential information redacted)

To ensure management buy-in a full-day “Think Tank” workshop was conducted with the Heads of Engineering and key managers of all three product lines (10 participants in total). The objectives of the workshop were the following:

- Review the proposed KPIs, adjust definitions where necessary
- Identify missing KPIs, define new ones where needed
- Discard unnecessary or redundant KPIs
- Agree on common definitions

In the first part of the workshop, however, the participants had to agree on common engineering-related reporting requirements, asking themselves the central question “What do I need to know to run my business in a way I meet the strategic targets of the Products Division?” (see figure 1).

Using a card technique, the following engineering-related reporting requirements – or information needs – were identified:

A. Project cost performance
B. Project progress performance
C. Quality of design
D. On-time delivery performance
E. Engineering staff load / capacity situation
F. Staff productivity

The first two information needs are comprehensible given the fact that the Heads of Engineering are responsible for a whole portfolio of development projects each with a budget of up to several million Dollars. Still, before the project, they had quite limited means of reliably identifying budget overruns and / or delays. Information needs C and D are connected as poor-quality design (design flaws, not meeting required weight or performance criteria, etc.) could jeopardize the timely completion of engineering deliverables like drawings, BOMs, etc. for a functional component (see 2.1). The need to obtain transparency about the capacity situation explains itself from the need to assign engineers with the right skills to the right tasks, considering the current project portfolio and, if necessary, to outsource tasks to external suppliers. The rationale behind knowing the staff productivity is that engineers can either work on (customer-billable) projects or engage in “unproductive” tasks like training or administration.

Some initially identified information needs that were later on discarded. For instance, data for "Performance against target costs" was not available (as a general guiding principle, all KPIs to be defined during the workshop had be derivable from the new SAP system) and "Level of standardization" (driven by the question of one participating manager: "Do our engineers understand that their main job is to avoid changes as much as possible?") was found to be not reasonably measurable and subject to design-external influences like special customer requirements.
In the second part of the workshop, KPIs had to be defined that would satisfy the previously identified information needs. This was achieved by reviewing the prepared "long list" (adjusting definitions and discarding unsuitable KPIs) and, again, using a card technique to identify new KPIs. The result is summarized in table 1.

Table 1. Finally selected Engineering KPIs

KPI	Definition / calculation	Information need satisfied
Outsourcing rate	Number of external partners / Number of own engineering staff	E
Engineering Utilization	Allocated demand of active projects [h] / Total available productive capacity [h]	E
Engineering Productivity	Total work time booked against billable projects [h] / Total contractual work time [h]	F
Cost Performance Indicator (CPI)	Budgeted cost of work performed [$] / Actual cost of work performed [$]	A
Schedule Performance Indicator (SPI)	Budgeted cost of work performed [$] / Budgeted cost of work scheduled [$]	B
Engineering On-Time Delivery (OTD)	Number of FCs released on time / Total number of FCs	D
Engineering First Pass Yield (FPY)	Number of FCs submitted without rejection / Total number of FCs	C

All information needs (see above) were covered. Note that the KPIs "Engineering OTD" and "Engineering FPY" relate to the overall production schedule (see figure 2), thus measuring the Engineering Departments' ability to feed the internal supply chain.

2.3 Implementation

Following the months of the workshop, the KPIs were technically implemented according to the concept illustrated in figure 4, being part of the Management KPI Dashboard covering also the other process areas (see 2.1).
Following the "single source of truth" philosophy, all KPI-related data originates from the same system that processes all business-related data (budgets, schedules, orders, etc.). From this Source System Layer, all KPI-relevant data is incrementally extracted to the Business Warehouse (BW) Layer on a regular basis (typically every 24 hours).
In the BW Layer, the actual calculation of the KPIs takes place. To calculate the KPI "Engineering OTD", for example, the BW system "counts" the number of released FCs within the specified reporting period, determines whether they have been released on time (comparing date stamps) and divides this quantity by the quantity of all released FCs. The BW system also stores historical data, making it possible to analyze trends.
The Reporting Layer provides the user interface of the KPI Dashboard, allowing the users to select KPIs, define filter criteria (e.g. narrowing down a KPI to a specific department) or to drill down to e.g. single projects.

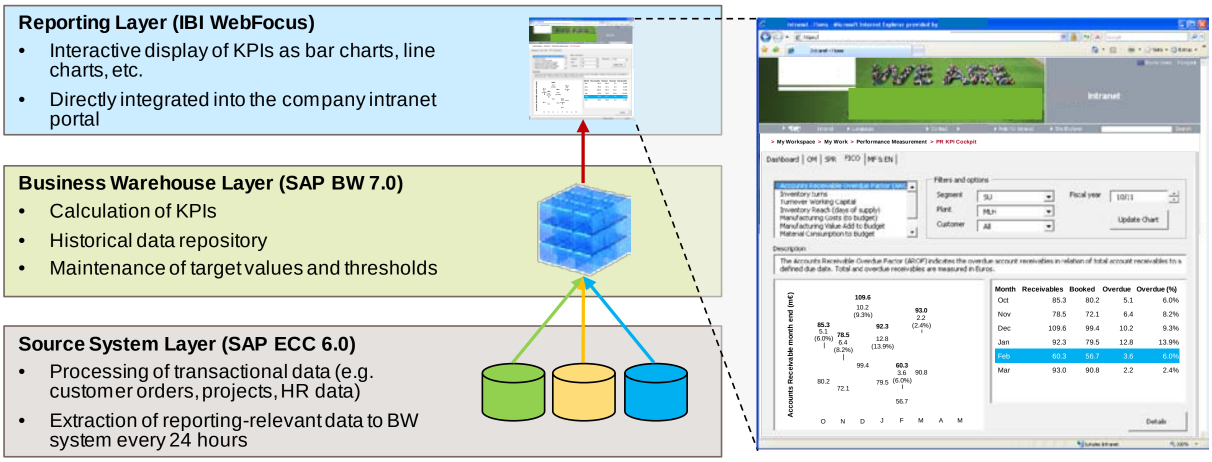

Figure 4. KPI Dashboard implementation concept

It should be noted that during the implementation phase, an ongoing alignment with the customer took place in order to reconcile technical constraints with management expectations, as well as clarifying open process-related questions.

3.4 Discussion

The presented case study is an account of introducing – from scratch – a KPI reporting framework into several engineering organizations of a large company division. Of the KPIs that became part of that framework, the only two that are remotely engineering specific are "Engineering OTD" and "Engineering FPY". The remaining KPIs would as well apply to any other project-oriented business (for example film production). Furthermore, both of the above KPIs do not track any project-internal milestones or design quality (however it may be defined).

It might be interesting to point out some KPIs that were initially proposed in the "long list" but were rejected during the workshop:

- **"Development Lead-Time":** start date of last development activity minus start date of first development activity
- **"Achievement of Design Targets":** percentage of achieved design targets (as documented at the beginning of the development project)
- **"Degree of Standardization":** the percentage of engineered parts / components within a finished product used in at least one other previously finished product

The argument against "Development Lead-Time" was that "apples would be compared with oranges" (or gas turbines with generators for that matter).

Even though the (quite comprehensive and well-documented) product development process of the client specified a mandatory documentation of quantitative design targets (sizes, weights, performance specifications), it would not have been possible to implement the "Achievement of Design Targets" as a KPI since it would have been too complex to extract this data.

"Degree of Standardization", even though regarded with favour and technically possible to implement, was ultimately rejected because "a more holistic approach" should be followed and that the topic would be "too big to be handled with a single KPI".

So the main finding of this case study is that the investigated engineering organization, when it was given the opportunity to implement a KPI reporting framework for the first time, preferred to manage its ED business mainly based on project management-related KPIs.

There are, however, circumstances specific to this case which need to be considered. Doubtlessly, the power generation manufacturing industry, with its long innovation cycles, strong emphasis on customer-order engineering and highly customized products is different from e.g. the automotive industry.

Also, the case study has to be seen in the context of the business transformation project as part of which it was conducted. This project imposed strong requirements for process harmonization and defined narrow boundaries for the IT implementation of the solution – the reasons why "Development Lead-Time" and "Achievement of Design Targets" were rejected.

Finally, factors like company culture, lack of management vision or the chosen consulting approach could have influenced the outcome.

4 CONCLUSION

Based on the KPIs that were selected by management, the case study supports the initial proposition that Engineering Design projects are basically projects. It also supports the view that standard project management KPIs can be used with some customizations specific to the nature and size of the company, the projects and the project teams. However, the authors consider that to confidently propose a set of engineering design specific KPIs that can be more easily adapted by project teams would require more studies like this in other engineering areas and in organization of different sizes. The fact that the company in this case is very mature and has a running SAP system has made it possible to harvest reliable data for the KPIs calculations. This is not always possible, and the shear amount of data that is needed can be indeed a hindrance to the implementation of such a measuring system in smaller organizations.

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