

Milestone-Oriented Usage of Key Performance Indicators – An Industrial Case Study

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Abstract

Background: Key Performance Indicators are a common way of quantitative monitoring of project progress in modern companies. Although they are widely used in practice, there is little evidence on how they are set, and how many are used in large product development projects. **Goal:** The goal of this paper is to explore how the KPIs are used in practice in a large company. In particular, we explore whether the KPIs are used continuously or only during short, predefined periods of time. We also explore whether the software-related KPIs are reported differently from the non-software-related KPIs. **Method:** We conduct a case study of 12 projects at Volvo Car Group in Sweden. We collect the data from the project progress reporting tools and triangulate them with data from interviews conducted with experts from the company. **Results:** KPIs are reported mostly before the milestones, and that manual assessment of their status is equally important as the automated data provision in the KPI reporting system. The trend of reporting software-related KPIs is very similar to the non-software-related KPIs. **Conclusions:** Despite the documented good practices of using KPIs for project monitoring, it is difficult to develop a clear status-picture solely using quantitative data from progress reporting tools. We also show that the trends in reporting software-related KPIs is similar to the trends in reporting non-software related KPIs.

1. Introduction

Monitoring large product development projects is a challenging task for the project management teams. Project managers, together with sub-project managers at different levels, quality managers and line managers, often use quantitative data to present the progress of projects and the readiness of their products [1]. Key Performance Indicators (KPIs) are used for the purpose of monitoring the progress, to capture this quantitative data and to provide the interpretation to it [2]. Although this practice is very common and well-known, there are not many studies on how this reporting is done in practice – e.g. how often the KPIs are reported, how many KPIs are used and how quantitative data is used in setting the values of the KPIs. In the literature, the classical use of KPIs is to continuously report and monitor the progress of the development, which usually leads to using KPIs for decision support and dissemination of information about the project status [3]. In our study, we set off to study how aligned is the literature evidence with the practice of using KPIs in a large company.

Embedded software development projects require synchronization between software-related and non-software-related sub-projects in order to result in a complete product. Project managers, however, often seek advice on whether the projects should follow more software-inspired agile way of planning (thus adjust to the software project management practices) or follow more strict, hardware-inspired project planning and monitoring (thus putting dedicated reporting requirements on software projects). In this paper, we explore how large software projects are managed and whether the usage of KPI is more software agile-like or hardware upfront planning-like.

1.1. Problem Statement

In this paper, we explore the problem of understanding the practice of using KPIs. In theory, the KPIs should be reported and monitored continuously, in order to provide an up-to-date status of the project. However, in practice, this continuous reporting requires resources and scales poorly with the number of KPIs. It is also the case that, if the number of KPIs grows, the probability increases that multiple KPIs monitor the same, or related.

Our contribution is in analyzing the KPIs both for software-related KPIs and for the entire project. The state-of-the-art in this area considers either only software development projects, or focuses on project-management aspects. Therefore, it is important to study the KPIs in embedded software projects, where the software development sub-project is contrasted to the non-software sub-projects.

1.2. Research objectives and questions

The general research methodology applied in our work is case study; a methodology which emphasizes close collaboration between industry and academia, and results in changes in hosting organizations. We set off to address the following research question – *How are KPIs for monitoring project progress used in practice in a large product development organization?* Steyn and Stoker [4] recognized this as an issue, and provided the evidence that different ways of using KPIs impact performance of development projects. The use of KPIs can also determine whether the company uses a traditional approach of performance monitoring, or whether the company uses modern principles of Neely et al. [5]. We study twelve projects and focus on such aspects of reporting as:

- How are the KPIs defined? – to understand the structure of the KPIs used in industry.
- How often are the KPIs reported in practice? – to explore the frequency and thus cost of reporting the KPIs, and to understand how timely the KPI information is.
- Who is responsible for reporting and acting upon the definitions of the KPIs? – to understand the stakeholders in the process of KPI reporting and decision making.
- How can we statistically identify dependencies between the KPIs? – to explore whether the KPIs are independent from one another, and therefore to understand whether the number of KPIs is sufficient or too extensive.
- Is there a difference between software-related KPIs and non-software-related KPIs? – to explore whether the software development KPIs are reported differently than non-software development KPIs.

1.3. Context

In our work, we study a large product development organization – Volvo Car Group, a Swedish vehicle manufacturer. We study 12 car development projects where a number of KPIs varies from 252 to 552 per project. We use the following definition of a KPI – *KPI (Key Performance Indicator)*

is a customizable business metric utilized to visualize status and trends in an organization. A KPI has an owner (a stakeholder according to ISO/IEC 15939 [6]), an interpretation (an analysis model according to ISO/IEC 15939) and is linked to a business strategy of the organization. This definition of a KPI is consistent with the use of the term in well-established methodologies as the Balance Scorecard [7].

The remaining of the paper is structured as follows. Section 2 presents the theoretical framing of our work. Section 3 describes the design of our case study. Section 4 presents the results and answers to our research questions. Section 5 discusses our results in the light of the existing body of knowledge. Section 6 summarizes our paper and presents our conclusions.

2. Background

In order to study the use of KPIs in the company we used a set of models of how the reporting process is done. The models are presented in Figure 1. The models are divided into four groups of activities:

- storage: the way in which information, needed to calculate the KPI, is stored – it could be either a database, such as a product article database or a persons’ assessment, such as if the quality of a requirement is sufficient,
- extraction: the way in which the information is provided to the KPI systems – it could be a manual reporting or an automatic extraction of the information using a script (for example by counting the number of defects reported in the database),
- analysis: the set of methods for analyzing the values of KPI assess the status (set the color of the KPI – green, yellow or red) – it could be an algorithm, using a set of pre-defined criteria, or a manual assessment,
- presentation: grouping activities related to the presentation of the material, which can also be either manual or automated – the manual presentation can be in a form of a MS PowerPoint presentation and the automated presentation can be a web-based dashboard with indicators [8].

These four groups of activities are based on the measurement information model defined in the ISO/IEC 15939 standard (Software and Systems Engineering – Measurement Processes), [6].

Our set of models for the theoretical framing of the KPI usage, comprises four models which have distinct characteristics.

The most basic model is the manual reporting, analysis and presentation of the KPI values, as initially presented by Kaplan and Norton, as part of the Balanced Scorecard methodology [9]. In this model (M), the focus of the KPI usage is on the periodical reporting and monitoring of organizational performance. The data to calculate the values of the KPIs is often available through individuals (e.g. by filling in reports) and needs manual assessment. The KPIs, in the M model, are often updated periodically and are prone to missing data points, but it is very flexible. This model can be observed in the studies discussion early adoption of the Balanced Scorecard [9].

The next model, which is more advanced, is the M-A model, where the extraction activities are automated, but the assessment of the KPIs status is manual. This kind of model is prescribed by many project management tools and methodologies, which focus on quantitative assessment of project progress and performance. An example of such a method is PRINCE2 [10]. The M-A model can be observed in modern companies utilizing the business intelligence tools. The KPIs, in the M-A model, are updated continuously and are analysed periodically; in practice this means the same disadvantages as the M model with a reduction of problems coming from the missing data points. The M-A model can be exemplified by such cases as surveys for customer satisfaction [11].

The next model is the A-M model, where most of the data extraction and presentation tasks are automated. The assessment of the values is, however, still manual. An example of such an assessment is the quality of the product under development by counting the number of defects discovered during testing. As the automation of the extraction and presentation is used, the KPIs in this model are often used as measures, and visualized as trends – since they are collected continuously. However, their assessment is periodical, which means that the status is available at certain points of time. Thus the KPIs in this model are more difficult to interpret, but easier to visualize [12]. An example of this kind of a model is the set of KPIs at Volvo Car Group where the data collection is automated but the setting of the color is manual [13].

Finally, the most advanced model is the A model, where all tasks are automated. The stakeholders of the KPI pre-define rules for analysis and these rules are applied automatically for the measures collected. This kind of model has been shown to be an efficient way of collecting the information and supporting decisions [14, 15], [16]. The KPIs which are used in this way require maintenance (evolving the criteria, updating the data extraction programs), but require no manual effort on a daily basis. It is the automation that makes it very attractive for modern companies. The main disadvantage of this model is, however, the fact that not everything can be calculated automatically, which in practice leads to the degradation to the A-M or M-A models. The main advantage, on the other hand, is the ability to provide the status assessment continuously; thus enabling the development of information radiators or dashboards spreading information across the project team. Examples of this type of reporting can be found at such companies as Ericsson.

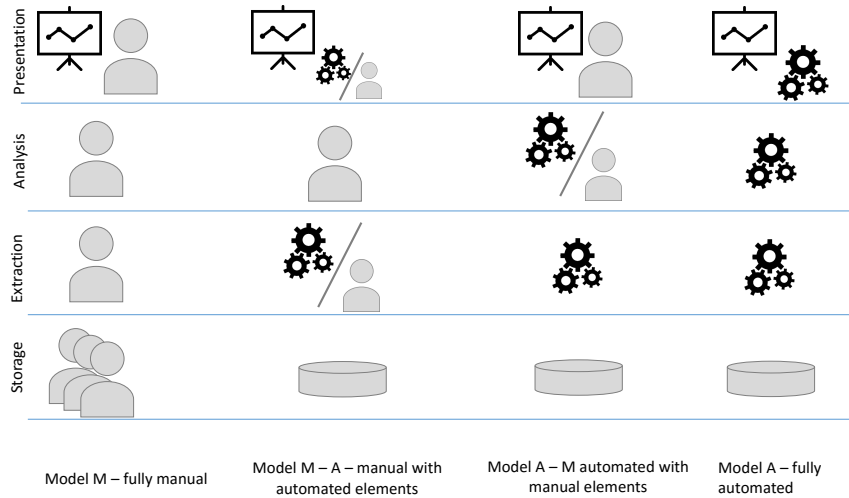


Figure 1. KPI reporting models

The set of models, which we use as the theoretical framework, allowed us to clearly identify patterns of which KPIs are used. The way of updating KPIs in these models, allowed us also to identify the possibility of visualizing the status in the long run – the potential for the development of dashboards.

3. Case Study design

In this section we describe the design of our study, following the guidelines by Runeson et al. [17].

3.1. Research questions

We set off to address the following research question – *How are KPIs for monitoring project progress used in practice in a large product development organization?* In order to address the question, we study a number of organizations within Volvo Car Group – involved in product development, manufacturing engineering, provisioning of parts for production and contract management. We study twelve projects and focus on such aspects of reporting as:

- How are the KPIs defined? – to understand the structure of the KPIs used in industry.
- How often are the KPIs reported in practice? – to explore the frequency and thus cost of reporting the KPIs, and to understand how timely the KPI information is.
- Who is responsible for reporting and acting upon the definitions of the KPIs? – to understand the stakeholders in the process of KPI reporting and decision making.
- How can we statistically identify dependencies between the KPIs? – to explore whether the KPIs are independent from one another, and therefore to understand whether the number of KPIs is sufficient or too extensive.
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Exploring these questions, provides us with the possibility to understand whether there is a minimum viable set of KPIs to be used in a project, and how to construct a dashboard for visualizing the status of the development in an automated way. For example, in order to construct a real-time dashboard as advocated by Azvine et al in the context of telecommunication industry [18]. Understanding whether the status of the KPI (or its color) is usually set using quantitative data from source systems, provides us with the possibility to automate the process of setting the KPI status and thus decrease the cost of project monitoring without the decrease of its quality.

Understanding of how KPIs are used in practice, requires a combination of analyses of data from different sources and, therefore, we triangulate two different sources of data collection – documents at the company (in the form of project status reporting tool), and interviews with stakeholders who report the progress.

3.2. Case and subject selection

The study presented in this paper has been conducted over a period of six months. The research has been conducted based on interviews with stakeholders at multiple units of the company – Electrical system and Electrical Propulsion, Powertrain, Chassi, Purchasing and Manufacturing Engineering. The interviews are complemented with the statistical analyses of historical KPI change data from finished and ongoing projects. The statistical analyses are done based on constructing co-dependencies, co-change models of KPIs for the selected set of 12 projects.

The projects are selected based on their characteristics – from minor year-model update projects to large complete new vehicle platform projects. We aimed to cover a variety of projects. Table 1 summarizes the characteristics of each project.

The minor model update projects are usually limited to updates of parts of the vehicle, which we call disciplines¹. (e.g. new infotainment software, engine control software update), and therefore are limited in scope, but not in the process as all process steps need to be conducted. Studying the smaller projects helps to understand, what the minimal number of KPIs is, whereas studying the large projects lets us understand how many KPIs large projects require. In the table, we use the

¹ Disciplines are the parts of development, e.g. active safety systems development, engine development, powertrain electronic control unit development, new production line development

number of KPIs as a proxy for size of the project, because in our analyses we found the number of KPIs to correlate with such project parameters as project length, effort and cost.

Table 1. Main characteristics of the projects studied

Project	KPIs	Characteristics
Project A (pilot)	386	Minor year model update of a mature car model. Development done on a single site, includes all disciplines.
Project B	552	New platform development project. Development done on a single site, includes all disciplines.
Project C	396	New functionality development for an existing platform. Single site, including a subset of disciplines.
Project D	382	New functionality development project. Development done on a single site, includes few disciplines only.
Project E	257	New functionality development project. Development done on a single site, includes few disciplines only.
Project F	442	New engine development project. Development done on a single site, includes few disciplines only.
Project G	305	New functionality development project. Development done on a single site, includes a subset of disciplines only.
Project H	252	New functionality development project. Development done on a single site, includes few disciplines only.
Project I	421	New functionality development project. Development done on a single site, includes few disciplines only.
Project J	342	New functionality development project. Development done on multiple sites, includes all disciplines.
Project K	494	New functionality development project. Development done on a single site (different than projects A-J), includes few disciplines only.
Project L	431	New engine development project. Similar to project F, but on a different engine. Development done on a single site, includes few disciplines only.

The number of KPIs reflects the size of the project as the larger projects tend to require more monitoring and control than the smaller ones. Therefore project B is the largest one, both in terms of the number of KPIs and the size (confirmed through interviews). Project A is in the middle of the size spectrum (386 KPIs in the set of 252 – 552 KPIs) and was chosen as a good pilot project to study in detail; we use the data from this project as examples in Section 4. Our industrial partners provided us with this information, also showed evidence for that. However, we cannot report these numbers outside of the company.

For the interviews, the subjects were selected based on their experience. All subjects have over 10 years of experience with project management, and in managing software and car development projects at the studied company. Each of the subjects was recommended by his or her manager as the most knowledgeable person in that area. All subjects were involved in a subset of the projects studied, although not all respondents were involved in all projects.

3.3. Data collection procedures

This research study was organized into four distinct parts, as presented in Figure 2 – statistical analysis of co-changes of KPIs and interviews about using the KPIs and future needs.

Figure 3 presents an overview of the research process for the statistical KPI co-change analysis. The process comprises four steps – starting from the exporting of the KPI change data from the database and finishing by prioritization of candidate KPIs to remove. As the figure shows, the export of the data from the database in step 1 results in one KPI change per project, and the

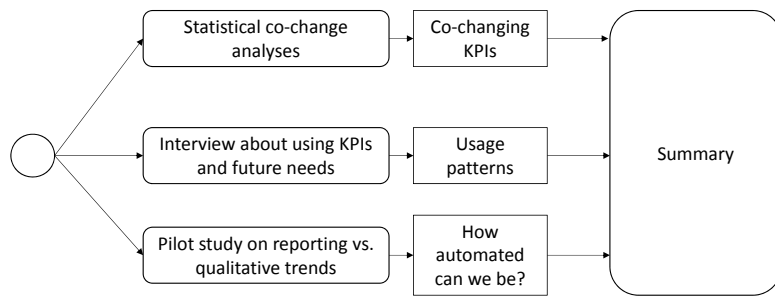


Figure 2. Overview of the research design

analyses in step 1 and step 2 are conducted per project. The analyses in step 3 and step 4 are done for all projects, by consolidating the results from each individual project.

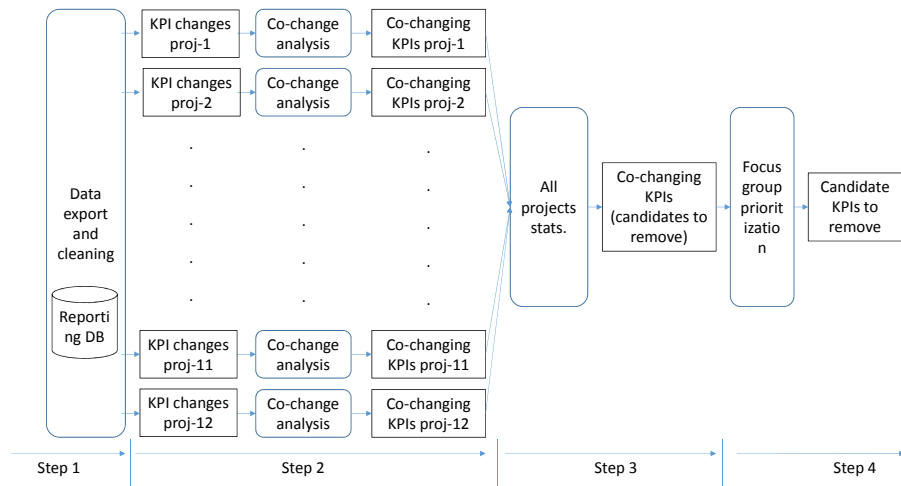


Figure 3. Overview of the statistical analyses

In step 1, the exports result in text files (.csv) with the change analyses in the format: <kpi name, value, change date >. Grouping these changes results in a statistics of how often each KPI changed together with another KPI.

We conducted the interviews with 12 different respondents – project managers (1 person), sub-project managers (6), unit project managers (4) and quality responsible (1 person). Each of these persons represented a different department at Volvo Car Group, and each has worked with a number of different projects (including the set of projects in our sample). They represented departments responsible for powertrain development, purchasing, quality management, electrical system development (including software) and interior development. The questions, which we asked were:

- Which elements of the construction are you responsible for?
- What is the main focus of your work with KPIs?
- How do you update KPIs today? - daily, before the milestone or another frequency?

- When do you discuss the status of the indicators and with whom?
- Which of your indicators are “automatically” imported from other systems?

For each question, we discussed the answers. We also asked about the dependencies between KPIs, their definitions, asked for exemplifying how the stakeholders work with the persons who define the KPIs.

3.4. Analysis procedures

The first analysis, of the patterns of changing KPIs, was done by visualizing the changes using a heatmap [19], [20], which is a graphical representation of contingency tables. The heatmaps allow us to:

- identify KPIs which change often in the project,
- identify which KPIs change only at a particular point of time, and
- check if progress reporting is done continuously or periodically.

We define the change in the KPI as *an event when a stakeholder actively updated the status of the KPI*, which means that there is an update event in the database where the KPI status was updated. Process-wise, this corresponds to the situation when a stakeholder needs to make an active assessment of the value of the KPI. He/she sees a notification on his dashboard and should make an active choice (even if it is only to confirm that the status is the same (e.g. still “green”). This means that the project manager at the higher level has a confidence that the KPIs status is up-to-date.

We define the co-change as the update of two KPIs in the same period of time – in our case during one day.

These patterns are used for further analyses of co-changes and quantifying these changes as percentage. The dependencies are identified using the method developed in our previous research to monitor co-dependencies in software modules [21], using the co-change model presented in Figure 4.

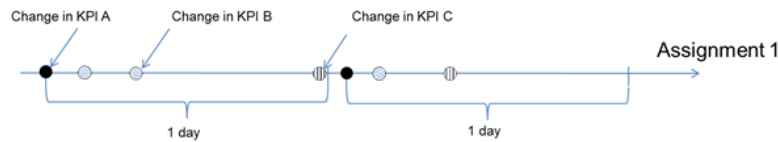


Figure 4. KPI dependency analysis model

The figure presents a lifeline of one assignment (e.g. a project) with the changes in KPIs. Two KPIs are considered as potentially dependent on one another, if they change within the same day in the majority of days. For example, if KPI-A changes 10 times during the period of 10 days (once a day), and KPI-B changes 8 times during the period of the same 10 days, then these two KPIs can be considered as 80% dependent. This kind of analysis allowed us to identify superfluous KPIs and to understand potential dependencies between them.

After calculating these dependencies in a single project, we summarized these dependencies for all studied projects. In this way, we obtained dependency pairs for all projects. In order to sort the changing KPIs, we use the $PRE(x)$ function which is defined as *a percentage of the projects which have a co-dependency of strength x or more*. However, there could be cases when the KPI is available only in one or two projects. For that we use the $AV(x)$ function as another criterion. The AV function is defined as *the percentage of the projects where the KPI is used*. For the analysis

purposes we use PRE(75) and AV with the cut-off point of 33% (dvs. KPIs present in at least 33% of the projects).

The data from the interviews was analyzed by the main author of this study using coding. The results were discussed with the reference group for the project, which consisted of the other co-authors and two line managers and two experts at the company.

4. Results

In this section we present the findings from our study, structured by research question.

4.1. How are KPIs defined?

The definition of the KPIs consists of two parts – the measurement method describing how to collect the data for the KPI and the decision criteria describing how to set the color of the KPI (red, yellow or green). This means that the definition corresponds to the groups of activities prescribed by our theoretical framework (Section 2 – extraction and analysis). The KPIs are visualized using a web portal as presented in Figure 5.

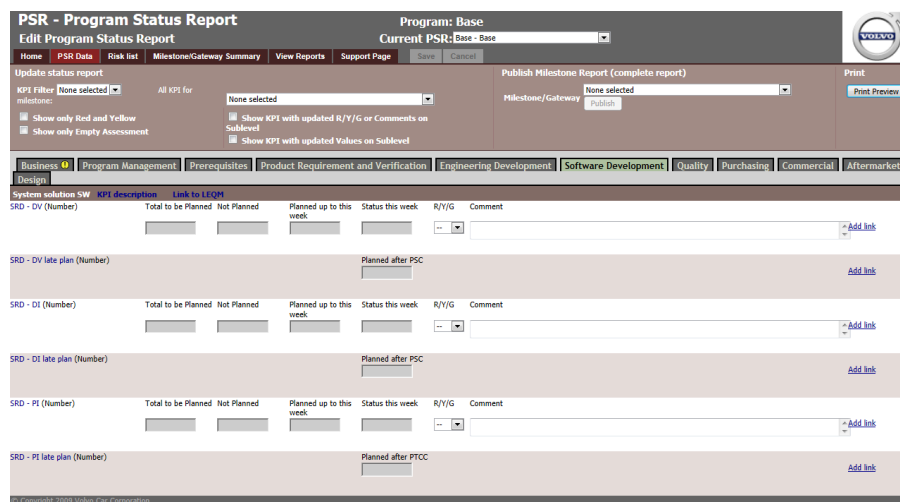


Figure 5. Web interface for status reporting

We have found that the measurement method for the KPIs can be defined in two ways:

- measuring that an activity has been performed (digital answer yes or no) – for example that a review of requirements has been performed, or
- counting a number of elements of a given type – for example how many defects of a specific type were discovered

These two measurement methods correspond to two models M-A and A-M. Both include evaluating the source systems before reporting the KPI – one is done automatically by extracting the information (counting the number of elements) and the other one is the measurement that an activity has been performed (digital answer).

We have found that these two measurement methods (and thus the reporting models) are used interchangeably, but the frequency of them changes over time. In the early stages of the project, it is common to use KPIs measuring the performance of an activity. In the late stages of the project

it is more common to use KPIs representing the counting of product elements – how ready the project is for release.

During the interviews, we found that this transition from reporting of activity progress to reporting of product readiness is common throughout the project. Counting a number of elements is used for product-related KPIs, as it is easier to count elements that are “ready” or “tested” towards the end of the project (where the product becomes more tangible for the project). The process related KPIs showed that an activity was performed and therefore they were more common towards the beginning of the project.

An example of the process-related KPI, which is calculated by measuring whether an activity has been performed, is the *Requirement reviewed* KPI for one of the early milestones in the project. The KPI has a color set to green when all requirements are reviewed, to yellow when not all requirements are reviewed but there is a plan how to review all requirements and red when not all requirements are reviewed but there is no plan how to achieve it.

An example of the product-related KPI is the software product quality KPI. The KPI is calculated by counting defects which have a certain severity. The rules for setting the colors of the indicator depend on the phase of the project. Although it is calculated only in the last milestones of the project the criteria for setting the values include the severity of the defects and the number of defects. A criterion for setting red at one of the milestones for this indicator is:

- Green: number of defects with Severity 1, 2, 3, and 4 is 0 in status New or Open.
- Yellow: Not meeting the target but with agreed plan in place to achieve target.
- Red: number of defects with Severity 1, 2, 3, and 4 is more than 0 in status New or Open or any (Severity 1, 2, 3, and 4) Passed Requested Target series.

The second type of KPI – based on counting the number of elements of a specific kind – are more quantitative in nature and that criteria for setting the colors (levels) of the KPI are clearer than for the first type of the KPIs – based on measuring that an activity has been performed.

From the interviews, we have found that the KPIs of these two kinds are mixed and that there is a need for more alignment. The interviewees also mentioned that having both types of the KPIs make it difficult to visualize the status of the project at a specific moment – as some of the “greens” never change (performance of an activity) and some of the “greens” might change over time (number of defects).

4.1.1. An example of a product-related KPI – Software Product Quality.

This KPI uses a defect tracking database as the source system. The summary of both the number of KPI updates per week (the top chart in the figure), and the data in the source system (the bottom chart in the figure), is in one diagram as presented in Figure 6.

The colors of the bars, in the top chart, indicate the color of the KPI reported. The colors of the bars, in the bottom chart in the figure, indicate the different status of the open defects in the database. The lines, in the bottom chart, show the cumulative number of defects reported in the entire project.

The criteria for setting colors of KPIs, are related to the timing and the number of open (non-resolved) defects. For example, in order to set the status to yellow, there should be at least one newly reported defect after a specific milestone in the project. In order to set the status to red, the newly reported defects have to come after yet another (later) milestone. This is the case in this pilot project, and our interviews have confirmed that the colors of the KPIs for this indicator are indeed set based on these criteria.

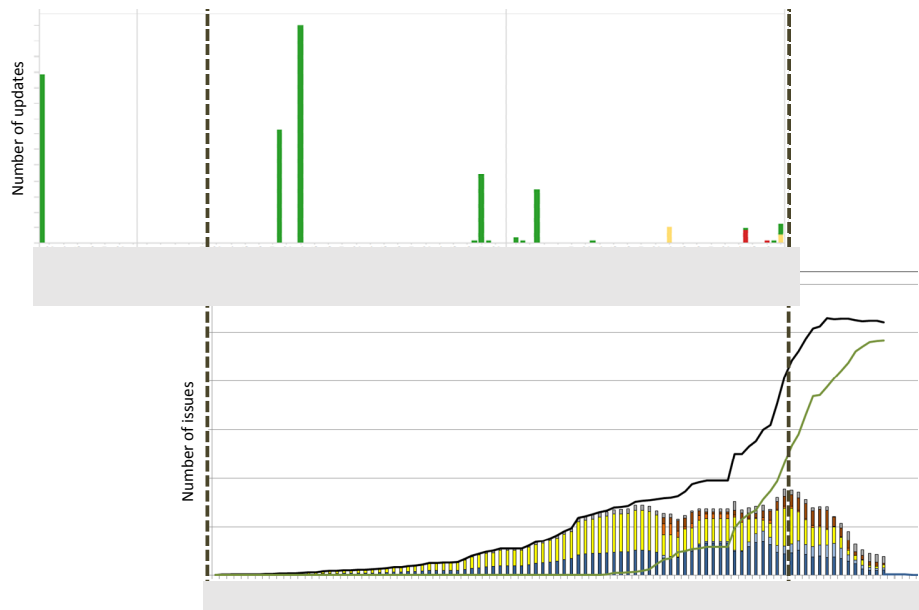


Figure 6. Comparison of updates of KPI and the underlying data from source system (defect reporting database). The vertical lines show alignment in time. Due to the sensitivity of the data the scales have been removed.

Since these criteria are so well defined, in terms of measurable quantities (number of defects in a specific status and milestone), the reporting of KPI could be supported by the pre-setting of the status of the KPI; thus reducing the burden of searching for data for the sub-project managers.

4.2. How often are the KPIs reported in practice?

In order to study the patterns of KPI changes per week, we calculated a contingency table which summarized the number of KPI changes per week. We used heatmaps to visualize it, as it is shown in Figure 7. As the figure shows there are visible “vertical” lines where a set of KPIs changes the status. This indicates that the project management focuses on “milestones” when reporting KPIs to the database. This finding was also confirmed in the interviews. The reasons for this can be the lack of use of the KPIs between the milestones, and the need to prioritize other assignments.

During the interviews, we also found that given the non-continuous update of KPIs, it is difficult to get an overview of the current status. If we draw a vertical line in the figure – a snapshot, it is not clear how “old” the status of each of the KPIs is.

To summarize the data, we use the histogram of the percentage of KPIs that change over one week as presented in Figure 8.

Figure 9 shows the frequencies of changes of KPIs per week. Each row represents a project and each column represents the percentage of KPIs that have changed per week. Each bar represents the number of weeks when a given percentage of KPIs changed.

As the figure shows, there is no project where over 60% of KPIs changed and in the majority of weeks less than 10% of the KPIs were changed. This shows that the A model is not applied at the company as that model is characterized by continuous update of KPIs. During the interviews we have found that the M model is not applied either as the KPIs are calculated based on the data from source systems (e.g. requirements database, project planning tools). The interviewees explained that, depending on the indicator, they apply either the M-A or A-M model.

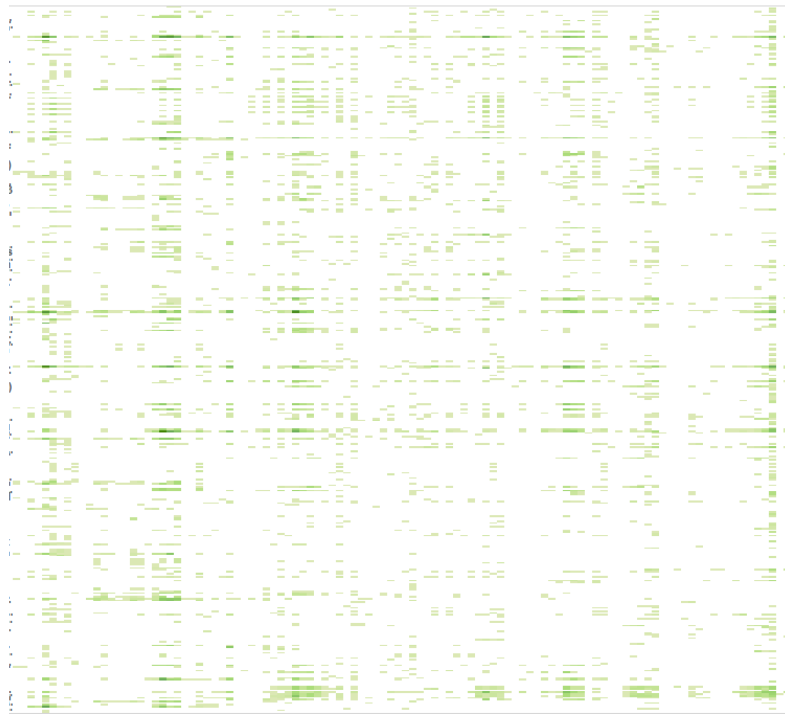


Figure 7. Frequency of reporting KPIs per week. Each row is one KPI and each column is one week; the intensity of the color indicates how often the KPI was updated during given week.

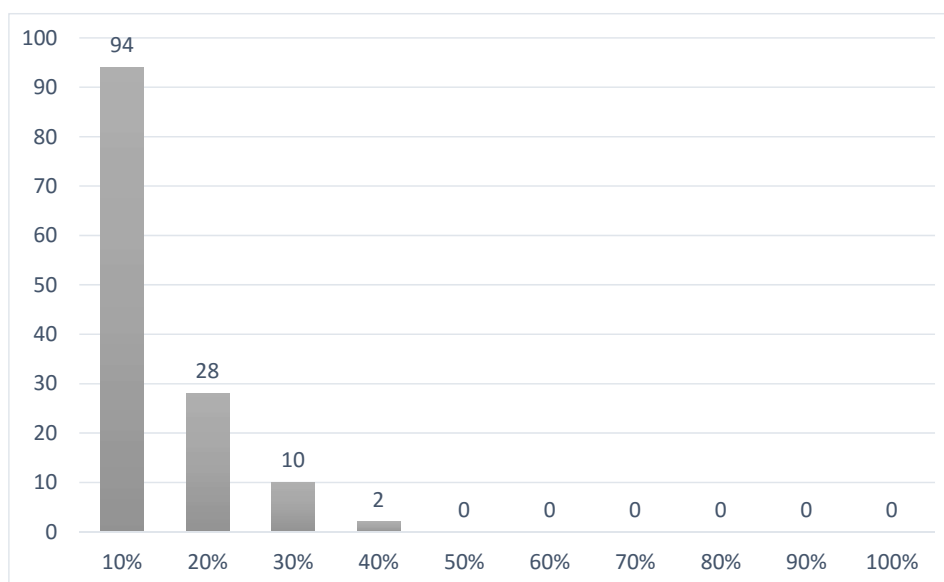


Figure 8. Histogram over the frequency of changes per week – each bar represents the number of weeks when the given percentage of KPIs changed.

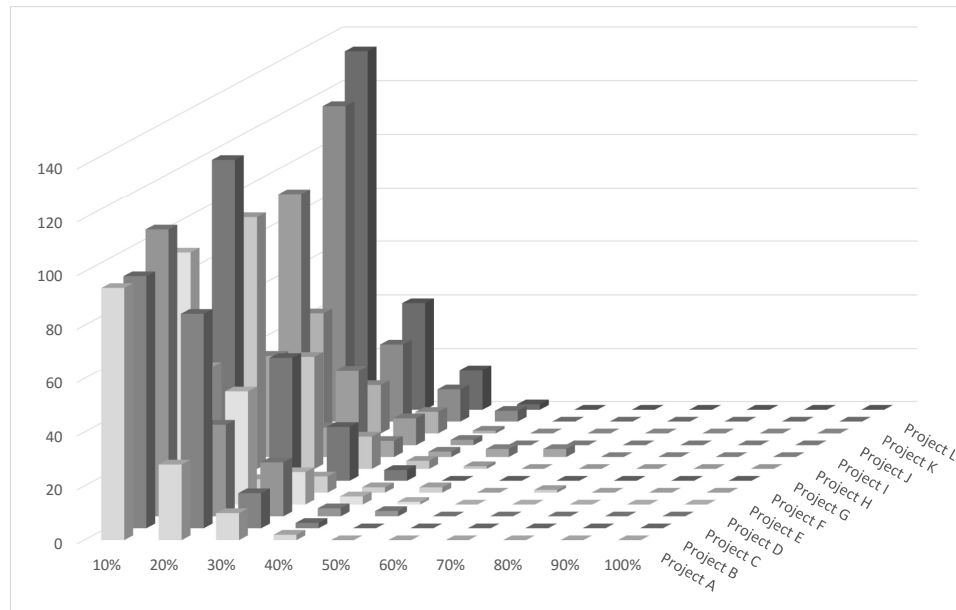


Figure 9. Frequencies of KPI changes in all studied projects

In the beginning of the project, it is often the M-A model which dominates, as the KPIs used at the beginning focus on the tracking of activities; whereas toward the end of the project it is the A-M model which dominates, as the product data is often used for KPI calculation.

From the interviews, we could find that this milestone-orientation is common – all interviewees supported that. They have also indicated that one always needs to comment on the status “red” and therefore the list of risk is an important complementary tool. Each risk can be linked to a KPI and the risks are discussed during the project status meetings.

The interviewees showed that, in practice, the A-M model is challenging as the continuously changing data is difficult to judge the status of. In the cases for continuously changing data, one needs a fully automated A model to keep the pace of assessment of the status.

Another challenge identified, which requires the automated A model, is the fact that import of data from the source systems can be out-of-sync due to the large complexity of the source systems. Interdependencies between systems make it difficult to import all the data at once, and therefore the imports have varying frequency – which makes it difficult to make manual assessments (one does not know exactly how “fresh” the numbers are, i.e. has the data of low timeliness).

4.3. Who is responsible for reporting and acting upon the definitions of the KPIs?

From the interviews, we have found that the KPIs are reported by project managers and their sub-managers. However, they are always approved by the line managers or the project management team.

The sub-project and unit project managers are responsible for the assessment of the KPIs (setting the color based on the criteria) and for presenting the KPIs for the main project manager. When they make the assessment of a KPI, they present their assessment to the line managers of

their respective unit or group. The manager approves or adjusts the assessment of the KPI. We have found that it is formally the manager (in all cases), who is responsible for the KPI.

After the manager has approved the KPI, it is the sub-project or unit project manager (depending on the level), who presents the KPI to the next level up. Sub-project managers present the KPIs to the unit project managers and the unit project managers present the KPIs to the main project manager.

The total project status is presented by the main project manager to a project steering group. The project steering group is outmost responsible body for the project and can make such decisions as increasing the funding of the project, if needed.

4.4. Which KPIs are co-dependent on one another?

In this analysis we use the co-change analysis. When presenting the results, however, we list the KPIs based on two parameters according to our research methodology described in Section 3:

- PRE(x) function which is defined as *a percentage of the projects which have a co-dependency of strength x or more*, and
- AV function which is defined as *the percentage of the projects where the KPI is used*

Together with the company stakeholders, we have identified the thresholds for these two functions to be: $PRE(75) = 100\%$ (meaning that in all projects where the KPI pair is present the strength of dependency is 75%) and $AV = 33\%$ (meaning that the KPI pair is present in at least 33% of the studied projects, i.e. 4 projects). Applying these functions to the data set (over 244 000 pairs of KPIs), we have found 75 pairs that were manually reviewed by the stakeholders whether they overlap. Eight (8) pairs were found to be dependent on each other, 27 pairs were assigned for further investigation if the statistical dependency can be confirmed by experts, 3 pairs were already removed (after the end of the projects and before we finished our study) and 37 pairs were found to be false positives. The 37 KPIs, which were found to be false positives, were present in only 4 projects, whereas the eight pairs found to be co-dependent were found in all 12 studied projects. The 27 pairs assigned for further investigation were found in between 5 and 9 projects from the 12 projects sample.

The interviews revealed that the majority of the KPIs in the list of 75 KPIs were progress indicators. These progress indicators were used to indicate that a set of activities were successfully conducted based on the set of pre-defined quality criteria.

During the interviews, we have found that the KPIs which are related to a specific deadline are usually reported in the period 4 weeks before the milestone until 1 week after the milestone. The 4 weeks period allows the project (and subproject/unit project managers) to focus on the goal and report the KPIs which are important for assessing the completion of the milestone.

4.5. Is there a difference between software-related KPIs and non-software-related KPIs?

In this analysis, we identified which KPIs were software-related, and we conducted a correlation analysis between the software-related and non-software-related KPIs. We correlated the trends in the reporting of these KPIs. We have identified 20 KPIs to be related to software development activities. Once we identified these software-related KPIs we added the changes to these KPIs and created a time series for these changes. We then performed the same analysis for the other, non-software-related KPIs. An example of this chart is presented in Figure 10.

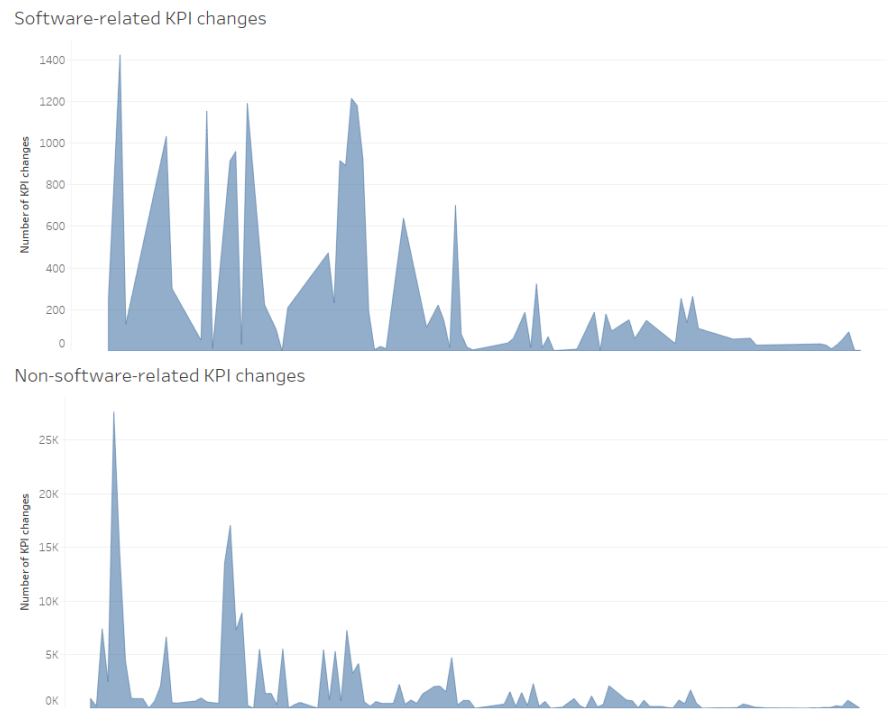


Figure 10. Changes in software-related and non-software-related KPIs per week.

The diagram indicates that the changes in the KPIs per week follow the same trend. In particular, the visual analysis shows that the peaks in the number of KPIs reported happen in the same time. Pearson correlation coefficient for these two series is 0.69, which is a strong correlation.

We can observe that the peaks, in the number of changes of KPIs, is similar. However, we can also observe that the software-related KPIs have more peaks. This can be explained by the fact that the software-related KPIs have higher similarity to each other than non-software-related KPIs. The non-software-related KPIs contain all other disciplines (except for software), which explains the lower similarity in that group.

Table 2 presents the results of correlation analysis for all studied projects.

Table 2. Pearson correlation coefficients for time series of number of changes in KPI values for software-related vs. non-software-related KPIs.

Project	KPIs	Correlation
Project A (pilot)	386	0.69
Project B	552	0.69
Project C	396	0.65
Project D	382	0.73
Project E	257	0.86
Project F	442	0.83
Project G	305	0.73
Project H	252	0.72
Project I	421	0.61
Project J	342	0.63
Project K	494	0.84
Project L	431	0.86

The table shows high correlations, which means that the trends are similar. This, in turn, means that reporting of software-related KPIs are similar to the non-software-related KPIs.

4.6. Summary – How are KPIs for monitoring project progress used in practice in a large product development organization?

Based on our results we saw the following trends in using KPIs:

1. The definition is standardized using three levels – red, yellow, green.
2. The trend in reporting software-related KPIs is similar to the trend in reporting non-software-related KPIs.
3. The definition of each of the levels is based on the ability to act upon the problems indicated by the KPI – if the status is yellow, then the responsible project manager has a plan how to get back on track before the next milestone; if the level is red, then the project manager registers the risks in the qualitative description of risks.
4. There is a progress from process-oriented to product-oriented KPIs over the project time – in the beginning of the project, when no product is ready yet, the KPIs control that activities have been done (e.g. requirement reviews is done). In the end of the project, when there is a product, the KPIs monitor that the product is ready for release (e.g. that all ECUs are tested to 100%).
5. The reporting of KPIs is done based on milestones – unlike the standard software development projects, the KPIs are used to check whether a project has achieved the degree of readiness required to move to another phase (e.g. whether all software components for an ECU are ready to be tested in a simulated environment).
6. The responsibility for the development of a KPI is given to measurement champions who have the necessary knowledge about the domain and the specifics of the product.
7. The responsibility for the reporting of a KPI value is given to the project managers at different levels as they have the responsibility that the product and project follow the set resources.
8. The responsibility for the formal approving of the KPI status is given to line managers of the relevant organizations, as these roles have the responsibility for resources in the company.

The above items show that the project management in the automotive sector, including embedded software projects, follows the classical, gate- and milestone-oriented principles. According to these principles, planning and following the plan are central.

The fact that the number of KPIs is between 252 and 552 shows that the complexity of the development is too high to change to continuous reporting of KPIs. Therefore, there is a need for combining the manual assessment with the automated data provisioning from source systems.

4.7. Validity analysis

In this paper we follow the framework of Wohlin et al. [22] and a more recent framework by Runeson et al. [17] in evaluating the validity of our research.

The main threat to the *external validity* is the fact that we study only one company – Volvo Car Group. Single-case studies can risk bias towards informants or the context. However, we believe that a broad sample of projects helps to increase the external validity at least above one project. We also see this study as an important contribution to studies of software development as part of larger context – car development.

The main threat to the *construct validity* is the potential mono-operation bias as we have conducted a study at a single company only. In order to minimize this threat by diversifying the project sample – we chose a sample of 12 project with different characteristics, scopes and project

teams. Another threat which we minimized is the mono-method bias – using a single measure of co-dependency. We minimized it by using the same measure as in the previous studies where the validity of finding co-dependencies was established (although for a different type of measured entity). Finally, we identified a threat related to the measurement of co-change, namely the fact that some co-changes are purely random. To minimize the threat, we used the $PRE(x)$ and $AV(x)$ functions to set thresholds to reduce the probability of capturing a random change as a valid co-change. We have also identified a threat that the stakeholders do not update the status of the KPI when the value changes and the status remains the same (e.g. "red"). This is a threat that we could not minimize as we do not have a measurement method to capture this situation, therefore we found that this situation is seldom in the studied company.

Using our theoretical model, as shown in Figure 1, we constructed the study so that we code each answer based on the elements of the model. This introduces the risk of missing an important information, which is limited when using alternative methods (e.g. grounded theory). However, we chose to use the model as we intended to use interviews as a triangulation method to the quantitative data analysis.

In our study we intended to minimize the risks related to the *internal validity and reliability*. Therefore we used triangulation of data collection methods – statistical and archival analyses (KPI data from the database) and interviews. The triangulation allowed us to check the root causes of the patterns visible in the statistical analyses – e.g. identifying potential causes of KPIs being co-dependent.

In general the main threat to the *conclusion validity* of such studies as ours – identifying co-dependencies in numerical data sets – is drawing conclusions based on only on statistics. Therefore in this study we decided to triangulate the data sources (document analysis and interviews) and triangulated interviewees and their roles (multiple organizations within Volvo Car Group and multiple roles). By this triangulation we also minimize the risk that the results are biased or represent a specific part of an organization.

Since we use interviews in the study, we are aware of the conclusion validity threats related to overinterpretation. In order to minimize these threats, we confirmed the findings during a workshop with all interviewees and in another workshop with a reference group for the project (consisting of technical experts and managers).

5. Related work

In a recent study Todorovic et al. [23] explored the types of KPIs which can be found in organizations focused on projects. They have found, which our study confirms, that there are such types of KPIs which are related to progress and such that are related to performance and that the latter are more challenging. We can thus conclude that the theoretical models, published in software engineering literature about KPIs, need extensions to improve the formulas by adding uncertainty components or temporal aspects or both. In a recent study, Todorovic et al. [23] identified properties of KPIs which are important for our study too – a KPI being actionable and measureable. In their study Todorovic also postulated the fact that there is a difference between measures and KPIs which corresponds to similar difference between the progress KPIs and performance KPIs. The latter are naturally important, but as Todorovic et al. state, also very challenging because in the project oriented organizations the progress KPIs tend to be the most common ones. However, even though we could observe that in practice the theoretical framework of Todorovic et al. can be applied, their models cannot because the models are based on the assumptions that there is a known and updated status in the moment when the model is applied.

Pilgoret [24] lists a number of KPIs which are important for modern project managers. The list includes both process and performance KPIs, but does not show when and how the KPIs should be reported. In our study we provide new evidence showing that not all KPIs are equal and that they are reported only when necessary. The evidence that the KPIs are not reported continuously and at the same time they are reported more than once per project means that there is a change in the way in which KPI are traditionally used. An example of such a study is the study of Pilorget [24] who shows the estimations of a number of KPIs (although much less than the number found in our study) only once during the project. Since the KPIs change and get updated this means that methodologies like that need to be adjusted to support more continuous re-evaluation of the project status value and should include the temporal component – how "old" or "stable" is the data in the KPIs.

Colin and Vanhoucke [25] presented a recent study on statistical performance control approaches for project monitoring. The results recognized the challenges with continuous monitoring of project status with the KPIs, which we address in our work.

The use of KPIs is very common in the field of corporate performance measurement and the predictions are that it will become even more important[3]. In the interview with the main experts behind the Balanced Scorecard approach this trend becomes even more evident. Therefore, in our study we intended to explore the use of KPIs in practice, and explore what the industrial trends in this area are.

In a study by Jaafari [26], the challenges with milestone-based project reporting have been recognized. The evaluation of the presented PH-Check approach in industrial context showed that the milestone-based assessment lead to efficient identification of shortcomings, and provide the ability for the stakeholders to react. This positive view of the milestone-based reporting is shared by some of the interviewees in our study.

As the modern product development evolves, so do the practices related to it. In a recent study of how the golden triangle in project management is perceived on the lowest levels of the organization, Drury-Grogan [27] found that quantitative information is of less value for lower levels. Instead, the consensus and understanding of the project goals become more important as the responsibilities of development teams increase. For cross-functional software development teams, as Drury-Grogan found, the product is of more focus than the project. One of our intentions was to understand whether these findings were valid for car development projects too.

The rationale behind this study was to follow up on the study of Steyn and Stoker [4], who have found that there is a significant difference between the performance of projects, depending on which project measurement methodology was chosen. They have found that measuring such parameters as contingency task allowance can increase the project performance. Although limited to a small number of measures, the study shed light that the use of measurement methodology can make a difference in projects. Therefore we set off to study the practice of how the measures (in our case KPIs) are used and when they are reported. In the light of the research of Steyn and Stoker [4], we could conclude that it is perhaps not the use of measures as such but the use of measures related to organizational goals (in the same sense as Todorovic et al.'s study) can make a difference. We have found that the performance oriented KPIs stimulate the goal orientation and can be (in principle) updated continuously which increases the chance of project success. This means that in project management measurement the separation of these two concerns – progress and performance oriented KPIs reporting should be postulated.

Raymond and Bergeron [28] have surveyed 39 project managers regarding the effects of the use of reporting systems in project management. The results showed that the use of project management information systems improved the efficiency and effectiveness of managerial tasks in projects. These results were important as an input to discussions with our industrial partners, and were confirmed

in this study – these kind of information systems provide the value. However, we found that it is important to find the right balance between the cost of reporting and the value obtained.

Marques et al. [29] presented a method for aggregating the status of KPIs (and metrics) in complex products. Their case study illustrated how feasible is aggregation in practice. Marques et al.'s approach is an alternative to using multiple KPIs at the total project level, which is the case of the studied company.

In our previous work, we have studied the use of KPIs in software development organizations exemplified by Ericsson [30], [31]. Our findings showed that the number of KPIs can be small and that the automation is the key. The results from the study, presented in this paper, are contradicting the results from our previous studies – lower degree of automation and larger number of indicators. This can be explained by the fact that, in the previous studies, we investigated software development projects, whereas in this study we investigated both software and non-software development project, as car development projects combine significantly more disciplines than software development projects.

Sanchez and Robert [32] provided a framework for defining KPIs, where they combine the standard KPIs like the earned-value indicator with the indicators related to risk management. By analyzing the pattern of reporting risks in the studied projects, in our case study, we provide evidence that this kind of combination is very much needed, as the risk-view of the KPI provides a more complete view on the project performance.

Choosing a set of metrics and KPIs for monitoring of projects have been studied in the Netherlands [33], with the results that the most important determinant of the success of KPIs adoption is the behaviour of the organization. The studied organizations identified a gap between the research and development function and the R&D department's responsibility which can be observed in the studied projects - the discrepancy between the process and project.

The quality of the KPIs have also been studied in a number of contexts, but an interesting study has been presented by Spangenberg and Göhlich [34], who study how to construct roadmaps of mechatronic software systems using KPIs. In their context of transportation systems, the technology readiness levels were combined with the goal-oriented KPIs, such as the carbon dioxide emissions, in order to allow for simulation of project outcomes. Our study provides the evidence that this kind of goal needs change in the mindset of the project management, as the KPIs are progress oriented at the beginning of the project. However, this kind of simulations are theoretically possible towards the end of the project, where the focus shifts towards product-oriented KPIs.

Lainhart et al. described the methodology for software project governance – COBIT, [35] – which provides a holistic approach to managing software projects. Our work provides an evidence that milestone-oriented project monitoring (as described in COBIT's processes part) is an important industrial practice.

Finally, we could see our work as an input to planning measurement programs using frameworks like GQM+Strategies, [36], [37]. GQM+Strategies helps to establish and evolve measurement programs by defining KPIs and relating them to company strategies. Our findings, that the KPIs are used when assessing milestones, can be an input to defining KPIs which are to be used in the way familiar to the automotive software engineering industry.

6. Conclusions and Further work

In this study we explored the question of *How are KPIs for monitoring project progress used in practice in a large product development organization?* We set off to study how the KPIs are used in practice by studying 12 car development projects at Volvo Car Group. We used interviews and

statistical co-dependency analyses to explore how many KPIs exist and how often they are reported. We used four theoretical models as a reference for our analyses.

Our results show that the number of KPIs used in projects oscillates between 252 and 552 and captures the complexity of the product as well as the complexity of the project to develop it. Over time the projects change the focus from activities (i.e. what has been done in the project) to product readiness (i.e. what needs to be done in order for the product to be ready for launch). The number, diversity, frequency of updates and the change of focus over time show that the studied company is very mature in the use of KPIs. The results from our investigations supported the company in identifying KPIs which can be dependent on one another (a situation quite possible in such a large data set).

The KPIs for embedded software development are correlated with other KPIs. This implies that, regardless of the applied software development methodology, progress reporting can follow the standard, milestone-oriented progress reporting. It means that companies have some flexibility in changing their ways-of-working within the given frames of strict non-software development projects.

Our further work is an in-depth study to optimize the set of reusable KPIs for an embedded software development project, and to evaluate its feasibility on more cases. This optimal set would help the managers to benchmark the projects against each other, quantifying the performance of the project portfolio over time.

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