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Improving presentations of software metrics indicators using visualization techniques

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ABSTRACT

To monitor and control software projects, companies develop and invest in measurement systems. A core component of measurement systems are the indicators (main measurements). Visualizing indicators can efficiently communicate the information to the users if done correctly, or mislead the users if not done properly. Indicators presentation and visualization is a topic that requires special attention due to the overwhelming information that the users receive and the lack of overview solutions that drive users in missing the "big picture".

In this master thesis visualization techniques for presenting indicators are evaluated. As a result of this evaluation the most appropriate methods for presenting indicators are identified. Prototypes of visualizing indicators are developed and evaluated through interviews with engineers from a unit of a large global software development company in the Gothenburg region. The prototypes provide the users with four different solutions for presenting indicators. This study is performed at the IT University of Göteborg with a case study at the company.

AUTHOR KEYWORDS

Information visualization, software metrics, quality engineering, software engineering, indicators

1. INTRODUCTION

Following the statement "If you can't measure it, you can't manage it" [1], companies use metrics and measurement systems to monitor and control the status of their projects and products. A successful measurement system must be designed and developed based on the company policies and strategies in order to overcome the information challenge of managing huge amounts of data generated by their software applications [2]. Usually, a measurement system is composed of based measures, derived measures, indicators and different stakeholders that use the measurement system [3].

Indicator is a variable that communicates information to a stakeholder about the state or trend of one or more attributes of the system, expressing a specific value at a required time [4, 5]. According to Burkhard et al. [6] although the indicators are presented visually, people are surrounded by overwhelming information and miss the big picture, "that's why we research in new methods to visualize indicators [6]". Furthermore, the authors [6] argue that companies should focus on presenting the collected data in a way that communicates the "big picture" rather than presenting raw data in decorative tables. However, it is not a straightforward task to select the most relevant visualization technique for a particular goal or application, as no specific technique is suitable for all the problems [7-9]. Thus, we believe that a particular study is needed in order to select the appropriate visualization techniques for presenting software metrics indicators.

The goal of this master thesis is to identify and investigate viable/applicable visualization methods for presenting indicators and evaluate their applicability at the company.

The research question addressed in this master thesis is:
"How can we optimize the presentation of indicators in measurement systems using non-standard visualization techniques?"

By *optimize* we mean that the information is presented in a succinct way and all important information is presented. We consider *non-standard* visualization techniques to be techniques that are not currently used in software engineering, but are used in other fields.

This thesis is structured into six major sections. Section 1 introduces the field of the study, the problem area and the research question that will be investigated. Section 2 provides a concise assessment of the previous research work in the field related to this master thesis. Section 3 introduces the measurement system and its properties. Section 4 describes the methodology that will be used to answer the research question. Section 5 presents the empirical data collected during our research. Finally, section 6 presents the conclusions drawn from the research.

2. RELATED WORK

Regarding software measurements, the ISO standard ISO/IEC 15939 supports the composition of a software measurement process in a standardized way [3]. It involves the identification of appropriate measures that concentrate on the information needs of the stakeholder [3]. Nonetheless, although the ISO standard ISO/IEC 15939 provides to companies

a structured way to define, create, use and profit from the software measurement process, it does not include how to communicate the information needs to the users using visualization. Our study focuses on presenting the information needs identified during software measurement processes.

An important aspect that should be considered when presenting information in measurement systems is the quality of the information presented. According to Lee [11] ignoring the significance of the quality of information, the combined costs from the bad or corrupted data are estimated to be more than 30 billion US dollars. In relation to our work, we should ensure that the proposed visualization techniques will not be in contradiction or compromise in any way the quality attributes that the system should reflect. Lee et al [12] conducted a study on how quality attributes of information form knowledge. The results of the study [12] show how information quality attributes can be prioritized in order to increase the information and knowledge quality. We select some of the quality attributes based on the information quality attributes defined on [12]. We identify and prioritize the importance of those attributes in the context of our research through interviews.

In the area of software engineering the research on visualization techniques focuses more on code comprehension and understanding activities, for example [13-16], rather then on visualizing software metrics indicators. However, Burkhard et al. [6] discuss an innovative approach to present indicators. In their study a framework for visualizing strategies is used to communicate a number of indicators to different stakeholders in a way that motivates them and lead them to make decisions. Although the results are interesting, it is not feasible to use the framework as the whole measurement system should be changed, which is out of the scope of this study.

Outside the area of software engineering there are several papers [17-20] on how to present sustainability development indicators for countries. The sustainable development is one of the goals that a country tries to achieve [21]. To control and measure how sustainable developed a country is, indicators are used. The advantage of this particular indicator is that many studies on it have been conducted [17-20]. Because the phenomenon of sustainable development is complex and many parameters should be measured, a dashboard of sustainable development was created which summarizes the most important measures (indicators) in a single Figure. The idea behind the concept of the sustainable development dashboard is to present information from various areas to non-expert users [22]. The dashboard software uses the metaphor of a vehicle dashboard and is created in a way that enables comparison of indicators between countries [17]. This dashboard was adapted and evaluated as part of the thesis.

Information visualization is the process of presenting abstract and huge amount of data in a communicative way to the users [23-24]. The study of Voinea and Telea [16] shows how techniques promoted by the field of information visualization can be integrated into the configuration management process for software systems, whereas Amar and Stasko [25] present a design and evaluation framework for narrowing the analytic gaps and limitations of information visualization systems. Moreover, a meta-analysis of empirical studies on information visualization presented by Chen and Yu in [26] showed that users with the same level of cognitive abilities have tendency to perform better with interfaces that contained simple real life objects.

Visualization and interaction techniques are classified into categories in order to efficiently understand and organize them. The classification of visualization and interaction techniques assists us in recognizing these techniques when applied in applications. According to Keim [27] the visualization techniques used to present the information could be classified into:

- Standard 2D/3D displays (i.e. bar charts, scatter plots, pie charts)
- Geometrically transformed displays (i.e. landscapes, parallel coordinates). The aim of these techniques is to find transformations of multidimensional data sets.
- Icon based displays (i.e. needle icons and star icons). The basic idea of icon display technique is to map the values of the data item to the features of an icon [28].
- Dense pixel displays (i.e. recursive pattern and circle segments techniques). In this technique each data record is a coloured pixel and all the pixels in the

same dimension are into adjacent areas [27].

- Stacked displays (i.e. treemaps, dimensional stacking). The idea here is to present data partitioned in a hierarchical fashion [29]. In a treemap the given area is divided into areas that do not overlap, in accordance with the hierarchy of the tree [30].

Moreover, sources like [23, 28, 31] show the importance of interaction of visualization techniques and the usability benefits that interaction provides to the users. Keim [27] classifies the interaction and distortion techniques into:

- Interactive projection: The user can view all possible multidimensional projections of the data.
- Interactive filtering: ability to filter dynamically the data.
- Interactive zooming: The user is able to interact with the data by zooming on them and viewing more details.
- Interactive distortion: This technique allows the users to view segments of data with high level of detail and at the same time others segments of data are shown with a lower level of detail.
- Interactive linking and brushing: The basic idea is to combine different visualization and interaction techniques to minimize the weaknesses of a single technique.

Based on these classifications we evaluate the visualization and interaction techniques that are applied in existing applications.

3. MEASUREMENT SYSTEMS

In mature processes, measurements are the main gears of monitoring and controlling software projects [33]. Due to the large number of measurements that need to be collected for each project, measurement systems are used to collect, calculate and present measurements in an organized approach. Measurement system is a set of units designed to define the status of the units [32]. More specifically, a measurement system specifies the information that should be measured, how the measures and analysis results are to be applied, and how to determine the validity of the analyzed results [3]. In general, the core components of a measurement system are the based measures, the derived measures, indicators and the different stakeholders that use the measurement system [3].

A recent study on visualizing dependencies between measures in measurement systems was conducted by Johansson et al. [33] at Ericsson. In this paper a detailed description of a model of a measurement system at Ericsson is presented. According to Johansson et al. [33], the indicators that are on the top of the measurement system model, should fulfill the stakeholder's needs. However, the needs of a stakeholder vary in quantity and usually there is a considerable number of indicators to address these needs. Moreover, the indicator should not only fulfill the stakeholder's need but it should fulfill it in a fast, effortless and understandable way. Thus, the indicators presentation in measurement systems is of high importance.

4. METHODOLOGY

To conduct this research study, empirical research methods are used. There exist different types of empirical methods, but in our master thesis we perform a case study. We conduct the case study because we want to evaluate the presentation techniques for indicators in their natural context, under the current circumstances at the company. The following quotation by Sjøberg confirms that a case study is appropriate to achieve our aim: "A case study is an empirical inquiry that investigates a contemporary phenomenon within its real-life context, especially when the boundaries between phenomenon and context are not clearly evident [34]."

In this thesis we apply the holistic single-case study design [35]. We study one single case: the presentation of indicators in measurement systems at the company. The study is conducted at one organization (a unit of the company).

The research question that is addressed in this case study is:
"How can we optimize the presentation of indicators in measurement systems using non-standard visualization techniques?"
The objectives that should be achieved during this master thesis are:

1) To identify applicable visualization methods for presenting indicators. This objective leads to the following questions:

1.1. *"How is the information presented by other existing tools in the market?"* and

1.2. *"Which are the visualization methods identified from previous studies?"*

2) To assess requirements for presenting indicators. This objective is addressed by the following two questions:

2.1. "*What are the main requirements for presenting information in measurement systems?" and*

2.2. *"How are the quality attributes of information prioritized for presenting indicators in measurement systems?"*

3) To identify the users' expectations of the visualized information from the proposed visualization techniques. The following question derives from this objective:

3.1. *"What are the main expectations of the stakeholders and other users from the proposed visualization techniques?"*

The activity diagram presented in Figure 1 shows the execution process followed in order to accomplish our study.

To increase construct validity during this case study we use data triangulation [36]. Data triangulation is achieved by using different data collection methods described in each phase. Our case study is divided in four phases, presented in the following subsections.

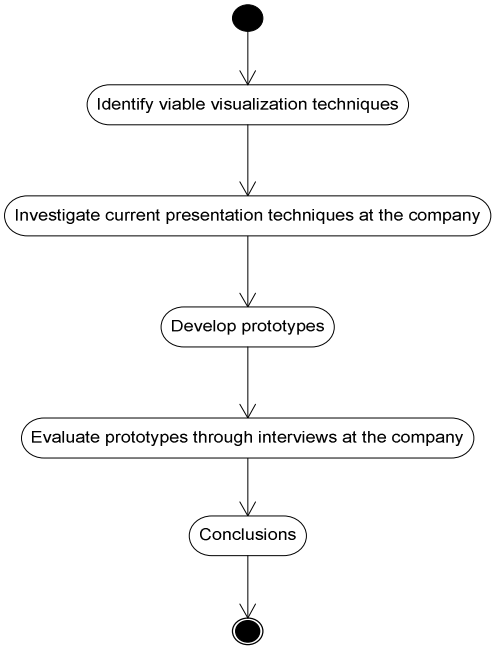

Figure 1: Execution process of the case study

Phase 1: Identifying viable visualization techniques

At the end of phase one, we should have a broad understanding of the different visualization and interaction techniques used to present data and indicators, not only in software engineering but in other fields as well. Furthermore, objective 1 (to identify viable visualization techniques for presenting indicators) should be accomplished. Hence, the exploratory research type is selected.

In this phase we use two types of data sources:

1. Existing visualization tools in the market

A comparison study is performed to collect the data from the existing visualization tools in the market. The areas of comparison are shown in Table 1.

Comparison Study Areas
Supported Data Sources: which input format are supported by the tool
Types of charts: what charts and figures can be presented in the tool
Interaction: How can the user interact with the presented data
Types of Outputs: how the presentation can be stored for future use (e.g. saving formats)
Extension mechanism: in which way plug-ins can be added to the tool
Other features (Dashboard): How to present all the data in a single presentation/view

Table 1: Comparison Study Areas

Furthermore, this comparison study is based on the results from three scenarios that will be applied in these visualization tools. The scenarios are:

a. Presentation of the overtime indicator on weekly basis.

   This scenario describes a situation when an employee monitor his/her work time and report whether they work overtime.

b. Presentation of the overtime indicator on daily basis by persons.

   This scenario combines the presentation of overtime for several employees; presentation for each employee is the same as in point a).

c. Presentation of three indicators (teaching, research and overtime) on weekly basis.

This scenario shows a more fine grain distribution of time into 2 pre-defined categories of tasks and additionally the overtime indicator as in point a).

To apply these scenarios in these tools, MS Excel file is used as data source.

This study assists us in establishing an understanding on how the information is visualized from these tools and what is different from the current system at the company.

2. Previous related work in the field.

Content analysis [36] is used as a method to collect and analyze the data from existing and relevant literature (i.e. published papers, books, etc.) using keywords relevant to our topic.

Phase2: Current presentation techniques at the company

In this phase we investigate how the information is presented by current measurement systems at the company. The objective of this phase is to identify and assess the requirements and expectations of the users for presenting indicators, which correspond to objective 2. The data collection method applied in this phase is the interview method, which according to Yin [35] is "one of the most important sources of case study information". Semi-structured interviews are selected in order to collect the information. The interviewer asks the questions based on the prepared guide. However, if an interesting issue is raised by the interviewee, the interviewer is flexible to ask the interviewee to elaborate. Table 2 shows the areas used as a guide during the interview.

Interview Areas	Expected Outcomes
Measurement systems	Acquire knowledge about the experience of the stakeholders with measurement systems
Use of the current measurement systems	Acquire a scenario of everyday use of measurement systems
Information presentation	Elicit requirements for presenting information
Quality of information	Identify and prioritize the most important information quality attributes for the stakeholders.
Technical details	Find differences between the measurement systems at the company and visualization tools in the market.
Problems and Difficulties	Identify opportunities for improvements

Table 2: Interview Areas

The interviews are conducted in English and the researchers have specific roles during the interviews. One of the researchers (the interviewer) asks the questions. The other researcher (the scribe) keeps notes. The scribe can also ask questions. The detailed list with the interview questions is presented in Appendix A. From the interviews we expect to elicit the criteria for selecting visualization techniques. The criteria that we are looking to define from the interviews should reflect the following areas:

- information quality,
- presentation of indicators,
- current systems limitations,
- stakeholder's expectations and,
- improvements

Documentation study [35] is applied in order to gain insights into the organization's processes and find new questions to ask during the interviews. The contact person at the company provides us with relevant documentation to our research.

After data collection, the next step is to qualitatively analyze the documents and data from the interviews. To analyze the collected data we will follow the Miles and Huberman's [37] approach, according to which, data analysis consists of "three flows of activity" [37]: data reduction, data display, and conclusion drawing and verification. To achieve data reduction and data display when analyzing the documents, we create a worksheet for each collected file that clarifies the context and its importance. The investigation of lengthy documents is done by searching for keywords in the first phase, then defining the significance of the paragraphs that contain the keywords and finally the results are documented.

The interview notes are coded using categorization and are sorted into the categories defined in Table 2. In this way we reduce the data and display them.

Our target population in this phase includes measurement systems. In our case study we choose a measurement system inspired by measurement systems used at the company, which we believe is representative for measurement systems used generally in industry.

Phase 3: Prototype development

After identifying innovative visualization techniques from phase 1 and identifying the expectations for presenting indicators in phase 2, we develop four prototype MS Excel add-ins which use the presentation techniques to present the indicators used in an example measurement system at the company. The prototypes are developed in Visual Basic for Applications in MS Excel 2003 at the IT University of Göteborg. MS Excel 2003 is selected due to the fact that the current measurement system at the company is developed using it.

In this phase, the iterative development process is chosen because it allows us to make modifications and improvements of the prototypes during the development. Our contact person at the company is involved during the development of prototypes (one meeting) before the prototypes are evaluated in phase 4.

Phase 4: Evaluating prototypes through interviews at the company

Finally, the prototypes developed in phase 3, are evaluated concerning their usefulness in industrial applications. The evaluation is done through interviews. In this interview, the interviewees are asked to evaluate the presentations using:

- the 5 point Likert scale, used in questions 3-6 (Appendix B):
  1 – Very difficult:
  2 – Difficult:
  3 – Normal:
  4 – Easy:
  5 – Very easy,
- the 10 point scale, used in question 13 (Appendix B)
  1- Totally insufficient;
  …
  10- Completely fulfils all information needs.

To conduct and analyze the data from the interviews, the same steps are used as in phase 2.

5. RESULTS

This section summarizes the results of our research and groups them by phases as designed in Section 4.

5.1. Results from the evaluation of visualization tools

From the research of existing tools in the market we identified the following tools:

1) Tableau [38],
2) Visokio Omniscope [39],
3) Spotfire [40],
4) TychoMetrics [41],
5) Inxight [42],
6) Ilog Jviews Charts[43],
7) Data Drill Integrated [44],
8) Microsoft Excel 2003 [45],
9) Dashboard of sustainability [46], and
10) Business Intelligence from Business Objects [47].

From these tools we evaluated only those tools for which we could obtain a full version or full function trial version. In this way, we could apply the scenarios, presented in section 4, in each tool. Consequently, we achieve a higher level of credibility of our results. The following list contains the evaluated tools:

1) Microsoft Excel 2003 (full version) [45].
2) Tableau 3.5 (30-day trial of fully functional version) [38].
3) Visokio-Omniscope 2.3-Beta (30-day trial of full version) [39].
4) Ilog Jviews Charts 8.1 (15-day trial of full version) [43]
5) Crystal Xcelsius Professional 4.5 (30-day trial of full version) [47].
6) Dashboard of Sustainability [46] (full version).

To visualize our results in an easy and understandable way we used a 2 dimensional check table (Table 3) where the X-axes contains the tools and the Y-axes contains the attributes.

The results are gathered using the same scenarios, presented in section 4, for all the tools, except from the dashboard of sustainability where the scenarios were not applicable. The following list presents some of the most important outcomes from this comparison study:

- These tools apply mostly the Standard 2D/3D display techniques (based on the categorization of the visualization techniques presented in section 2). This outcome reveals that the evaluated tools focus more on simple techniques which

are more familiar and easier to perceive by the users.

- The evaluated tools apply the interactive filtering, interactive zooming and interactive linking and brushing techniques (according to the classification of the interaction and distortion techniques, presented in section 2). As a result, this shows that these tools emphasize more on interaction techniques. This can be interpreted as a need of the user to interact with the visualized data in order to capture the required information. The emphasis on interaction techniques more then on visualization techniques could result as good or bad depending on the user needs.
- A conclusion about the best visualization tool can not be drawn.

	Excel 2003	Tableau 3.5 Trial Version	Visokio-Omniscope 2.3-Beta Trial Version	Ilog Jviews Charts 8.1 Trial Version	Crystal Xcelsius Profesional 4.5 Trial Version	Dashboard of Sustainability
Supported data source						
Excel files	√	√	√	√	√	
CSV files	√		√	√		
TSV files			√	√		
Text files	√	√	√			
XML files	√		√	√		
Access database	√	√				
JDBC		√	√	√		
ODBC	√	√	√			
Oracle	√	√	√			
Microsoft SQL server	√	√	√			
DB2	√	√				
MY-SQL		√				
PostgreSQL		√				
Firebird		√				
Netezza		√				
.IND file						√
Hyperion Essbase		√				
Chart's types						
Column	√				√	
Bar	√	√	√	√	√	√
Line	√	√		√	√	√
Pie	√		√		√	√
Scatter	√	√		√	√	√
Linkage analysis						√
Area	√			√	√	
Doughnut	√					
Radar	√			√	√	
Surface	√					
Bubble	√			√	√	
Stock	√					
Cylinder	√					
Cone	√					
Pyramid	√					
Pivot table	√		√			
Text table(cross tab)[38]		√				
Heat map[38]		√				
Graph[39]			√			
Highlight table[38]		√				
Gantt[38]		√				
Histogram[38]		√				
Tile [39]			√			
Tree [39]			√			
Portal [39]			√			
Map [39]			√			√
Web [39]			√			
Candle Stick [47]					√	
Multiple representation[43]				√		
Open-High-Low-Close [47]					√	
Cartesian [43]				√		
Porlar [43]				√		
High-Low [43]				√		
Combination [47]				√	√	

	Excel 2003	Tableau 3.5 Trial Version	Visokio-Omniscope 2.3-Beta Trial Version	Ilog Jviews Charts 8.1 Trial Version	Crystal Xcelsius Profesional 4.5 Trial Version	Dashboard of Sustainability
Interaction						
View underlying data	√	√	√	√		√
Filter data	√	√	√	√		√
Trend lines	√	√	√	√		
Display data using color	√	√	√	√	√	√
Display data using size	√	√	√	√	√	√
Display data using text	√	√	√	√	√	√
Sort data	√	√	√	√	√	√
Output's types						
Excel file	√	√	√			√
CSV file	√					
HTML file	√				√	
Txt file	√					
Tableau files		√				
PDF files		√	√			
Images		√	√			√
Access file		√				
Visokio file			√			
Powerpoint file			√			√
SWF file			√		√	
Multi view report			√			
Ilog jview charts file				√		
Crystal Xcelsius file					√	
Word file					√	√
Outlook file					√	
Extension mechanism						
VBA	√					
Other features						
Dashboard		√	√		√	√

Table 3: Results from the comparison study of visualization tools

Therefore, the conclusion for the best tool depends on the needs that each user requires to fulfil (e.g.. for exporting and presenting the visualized data to PowerPoint file the user should choose Visokio-Omniscope 2.3-Beta or if it is of the outmost importance to the user that the application provides extension mechanisms then Microsoft Excel 2003 should be used).

The next paragraphs describe the identified visualization methods from existing literature and from the comparison study of the visualization tools.

- Dashboard Overview

Form the comparison study we found the dashboard overview as a viable presentation method. The dashboard of sustainability presentation shows the current status of development indicators of a country [46]. Figure 2 shows an example of dashboard of sustainability. This presentation is based on a hierarchal structure. The first level – the circle in the center (labeled PPI) – shows the country development status. The country development status is defined by aggregating the indicators of each subarea (Environment, Economy and Social Care) of the country which are presented in the second level -the bigger circle-. Each indicator illustrated in the second level is calculated summing up the corresponding indicators of each subarea which are shown in the third level - the biggest circle - .

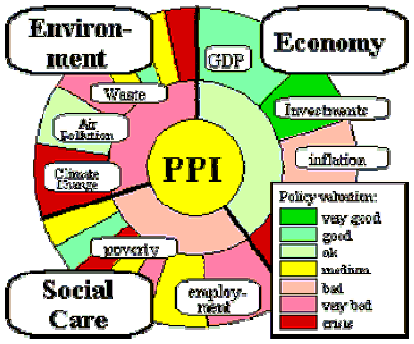

Figure 2: Dashboard of sustainability example [48].

This presentation corresponds to the disk-based visualization technique [30]. According to Diehl [30] this visualization technique uses efficiently the screen space exploiting it nicely.

- TreeMap Overview

Another technique to visualize the indicators is the TreeMap technique [28]. This presentation derives from the Tree method as displayed in Figure 3. Each node in the tree view is represented by a rectangle in the TreeMap view. Each child rectangle is placed inside the parent rectangle. Consequently, the TreeMap allow the user to distinguish the relations between the different nodes.

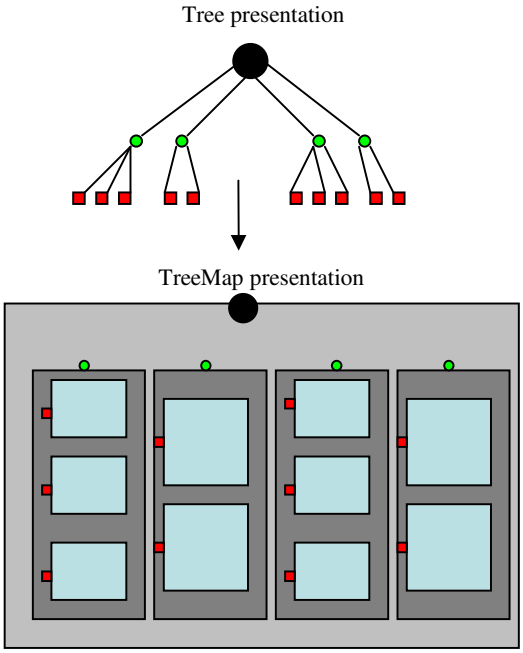

Figure: 3: Tree and TreeMap model

- Speedometer Model

Crystal Xcelsius Profesional 4.5 [47] uses the speedometer model (Figure 4) to present data. This model is inspired from the car's speedometer. The arrow shows the current value of the indicator while the colours are used to alert the users. This way of presenting information is interesting because it uses a real life object which is very familiar to most of the people.

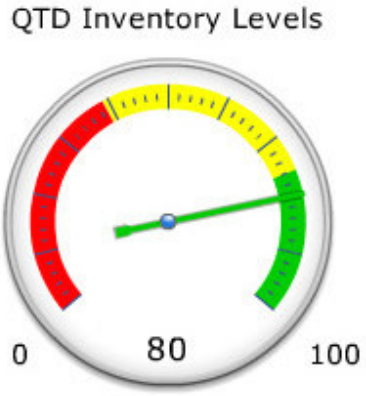

Figure 4: Speedometer model [46]

- Thermometer Model

Another way of presenting indicators is to use the thermometer model. Datadrill Intergrated software [44] uses this type of presentation, Figure 5. This model is also inspired from a real life object, the thermometer. The thermometer scale is separated into different colours which alert the users for the current status of the indicator. The "mercury line" shows the current value of the indicator.

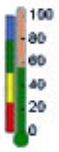

Figure 5: Thermometer model [44].

5.2. Results from the first round of interviews at the company

The interview is performed with a quality manager highly involved in the design and development process of the current measurement system at the company. The company, right now, has a number of complete measurement systems and the number is growing. The measurement systems are used to collect, calculate and present software metrics. At the company each measurement system is built for a particular purpose (information need), which is done according to the standard.

The information is presented in MS Excel files available from the web pages. The users have direct access to the indicators worksheet, as it is the first worksheet shown to them by the measurement system. In this worksheet the indicators are presented in a plain table with

coloured cells. This Table is separated in different areas (i.e. time, budget etc.), where each area has a corresponding indicators (i.e. development time, testing time, etc.). Also, the users have access to more detailed information which is presented by the measurement system in other worksheets.

Among the two most well known techniques of presenting the information, the colour encoding and the size encoding, colour encoding is used. For each indicator, in parallel with the colour the actual value of the indicator is displayed. To communicate the status of the indicators to the users, the responsible team for the measurement systems focused on indentifying metaphors that are familiar to the users. Consequently, the traffic lights model is used for the colour encoding of the indicators. The traffic light model contains three colours, green-yellow-red, to show the three different statuses, ok-warning-not ok, of the indicator. The interviewee stated that the colour encoding technique by itself has some limitations. Moreover, the users are not informed if the value is closed to the boundary of a colour definition in the analysis model (i.e. "how green is green for a specific indicator"). Figure 6 shows an example of how a model could have looked liked in the company.

Additionally, the problem of summing up the colours of different areas arises. In the current measurement systems the indicators are categorized in different areas. The status of each indicator is presented in the corresponding area; however the status of the whole area is not presented in one single indicator.

The existing measurement system that the interviewee is using, in principles fulfils the following needs:

1) displays the status of the project for different areas,
2) compares historical data,
3) automates the presentation of information and
4) the information is succinct and precise.

In principles the users can interact with the presented information:

1) View the underlying data,
2) Filter,
3) Sort the data and
4) Investigate in details the presented information.

The three main advantages of information presentation of the measurement system at the company according to the interviewee are:

1) The automated way of presenting the information,
2) The consistency of the information and
3) The easy access and readability of the information.

The three main disadvantages of the way that the information is presented by the current measurement system as stated by the interviewee are:

1) The static structure of the code,
2) The lack of dependencies between the indicators and
3) The missing trend lines.

Regarding the types of outputs, the current system offers only Excel files.

Finally, the interviewee was asked to prioritize different quality attributes using the 100$ test technique [10]. The results are presented in Table 4.

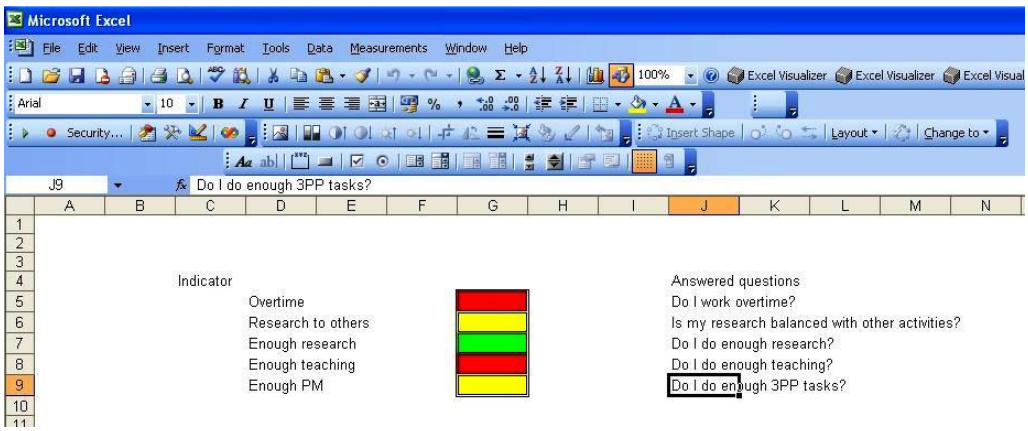

Figure 6: Current way of presenting indicators at the company

These results show that the interviewee considers accuracy as a prerequisite quality attribute of the measurement system. While all the other quality attributes are considered with quite the same level of importance. The questions from the first round of interviews are presented in Appendix A.

The following list presents the requirements that indicators' presentation should fulfil elicited by the first round of interviews.

1) Overview solution: The user should be able to view the status of all indicators.
2) Sum up areas: The indicators' status of a category should be aggregated in a single indicator.

Priority	Quality attribute	Question
51$	Accuracy	Is the information reliable and error-free?
8$	Accessibility	Can the information be accessed in any time?
8$	Value-added	Is the information helpful for the user and the organization?
8$	Timeliness	Is the current information required?
5$	Understandability	Is the information clear, unambiguous and simple?
4$	Objectivity	Does the information show a minimum of a bias?
4$	Completeness	How in depth is the information, does it cover all the levels?
3$	Variety	Is the information presented in different ways?

Table 4: Results from the 100$ test technique.

3) The current way of presenting indicators by the measurement system at the company does not answer to the question "How much yellow is yellow?" Meaning is the yellow closer to red or to green.
4) Locating metaphors familiar to the users
5) The user should de able to view more detailed data under his request.
6) The users should be able to present the indicators using a various number of colours according to their needs.
7) The presentation of information should be space efficient in order to fit in presentations slides when reporting the results from measurement systems to managers.

5.3. Prototype Development

In this section we present the four prototypes developed in this phase. The implemented techniques are innovative and not supported by MS Excel 2003 or 2007.

Prototype 1: Dashboard overview

The dashboard overview illustrated in Figure 7 presents the status of each indicator using colour encoding. The dashboard view is build by three circles. Each circle in the dashboard overview corresponds to a level. Each level contains one or more indicators. The first level, the smallest circle, displays the status of the whole project. Each project is divided in different main areas, for instance Time, Cost or Budget etc., which are presented as indicators in the level 2, the bigger circle. Each main area is divided in a various number of more specific indicators, such as Testing Time or Developing Time for the Time area. All these indicators are presented in the third level, the biggest circle.

The dashboard overview provides the user with the possibility to use a large number of indicators in level 2 and 3, being flexible to the user's needs. Moreover, the user is not restricted to a predefined number of colours indicating that the user is able to define the range of colours that will be used every time.

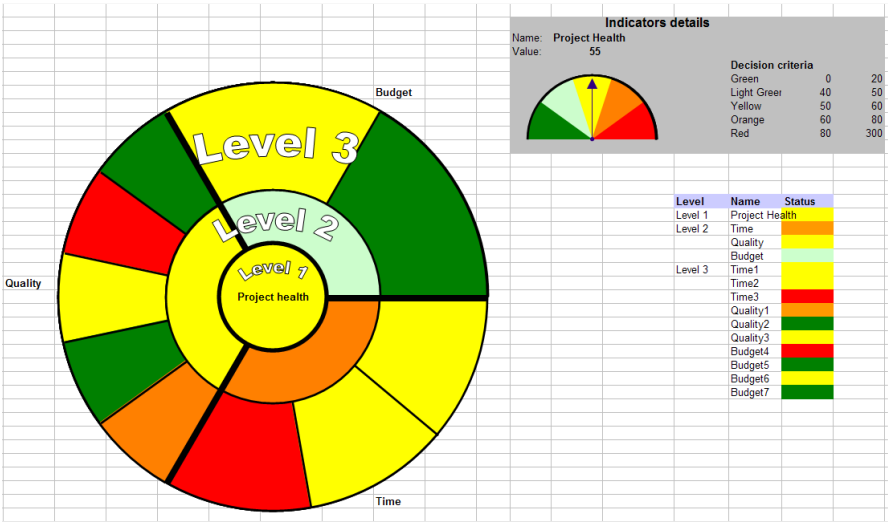

Figure 7: Dashboard Overview

Furthermore, the user can view the underlying data by clicking on each indicator. In the Indicators details view, the user is provided with the name of the indicators, the current value and the decision criteria. Also the arc view is embedded in the details view to inform the users if the value is closed to the boundary of a colour definition in the analysis model (i.e. "how green is green for a specific indicator").

Prototype 2: Arc View

The Arc View presentation illustrated in Figure 8 displays the status of each indicator using the speedometer model.

Each arc is divided in different coloured parts related to the decision criteria for each indicator and the status of the indicator is displayed by an arrow. The user is able to present a various number of indicators with different decision criteria and for each indicator an undefined number of colours can be handled. The position of the arrow in the arc shows the current value of the indicator, and in the same time the user can view if the arrow is closer to the previous colour or the next colour. In this way, this presentation informs the users if the value is closed to the boundary of a colour definition in the analysis model (i.e. "how green is green for a specific indicator").

Figure 8: Arc View

Prototype 3: Thermometer View

The presentation shown in Figure 9, based on the thermometer model, displays the status of every indicator in the project.

According to the decision criteria, the thermometer scale is separated in different coloured parts. The bulb of the thermometer present the current status of the indicator and the "mercury line" presents the level of the current status.

In the same way as in the Arc View, the thermometer presentation displays not only the status of the indicator but also the level of the current status, showing to the users if the value is closed to the boundary of a colour definition in the analysis model (i.e. "how green is green for a specific indicator"). This is possible by the position of the "mercury line" in the thermometer from which the user can view if the "mercury line" is closer to the previous colour or the next colour. The user is not limited in using a constant number of indicators or colours for each indicator.

Prototype 4: TreeMap Overview

The last prototype is the TreeMap Overview illustrated in Figure 10 based on the TreeMap technique described in [28]. The TreeMap view is build using rectangles. Each rectangle in the TreeMap overview corresponds to an indicator. There are three levels in this presentation that contain one or more indicators. Following the same hierarchical model as in Dashboard overview presentation the first level presents the whole project health. The second level displays the indicators that correspond to the main areas for instance Time, Budget or Cost etc. Each main area contains a range of indicators that are presented in the third level such as Testing Time or Developing Time for the Time area. There is no limitation considering the number of the indicators in level 2 and level 3. Moreover the user can apply the colour encoding technique using a various number of colours.

Furthermore, the user can view the underlying data by clicking on each indicator. The arc view is included in this presentation so that the user can view by the arrow's position if it is yellow closer to green or to orange. In the Indicators details view, the name of the indicators, the current value and the decision criteria are presented to the user.

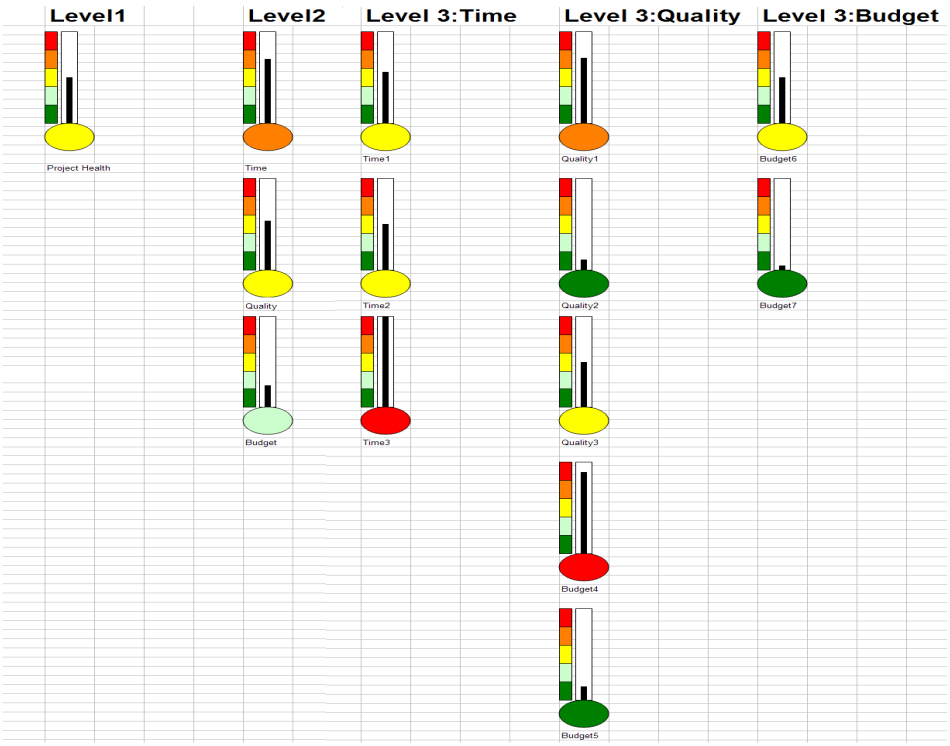

Figure 9: Thermometer View

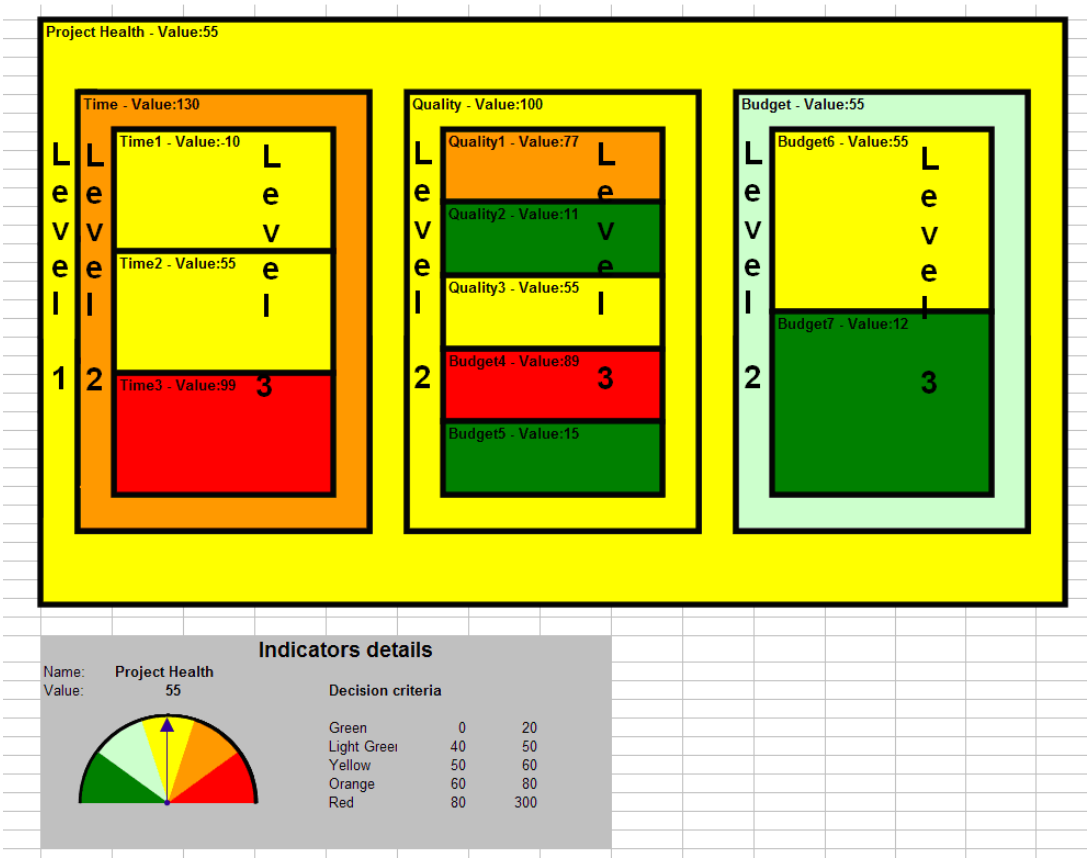

Figure 10: TreeMap Overview

5.4. Results from the second round of interviews at the company.

This section presents the results from the second round of interviews at the company. In this round three interviewees (a Quality Manager, a Main Project Manager and a Quality Manager) participated in the evaluation process of the three prototypes: Dashboard Overview, Arc View and Thermometer View. The TreeMap Overview prototype was not evaluated as it was considered as not easy to understand. The three prototypes are integrated in the current measurement system at the company which is evaluated as well.

The main scope of the interviews is to evaluate how the information is presented by these three prototypes and the current presentation at the company. The following paragraphs present a summary of the advantages and disadvantages for each presentation as resulted by the interviews.

- **Current presentation at the company:**
  - *Advantages*
    1) The most appropriate presentation for finding the detailed value of the indicator.
    2) Easy interpretation of the results.
    3) Direct access to the value of the indicator
    4) Fulfils to the largest extent the information needs of each interviewee.
  - *Disadvantages*
    1) Does not aggregate all the indicators of the same area in one indicator.
    2) The trend lines and dependencies between the indicators are missing from the presentation.
    3) It is not easy to capture the "big picture" of the project's status.
    4) It is not a space efficient presentation.
    5) Too much information is presented in the plain Table.
    6) The users are not informed if the value is closed to the boundary of

a colour definition in the analysis model.

- **Dashboard overview**
  - *Advantages*
    1) The best presentation to overview indicators and capture the "big picture".
    2) Easy interpretation of the results.
    3) Has the potential to aggregate all the indicators of the same area in one indicator.
    4) A convenient way to present indicators to the others, due to its space efficient property.
    5) The user can view all the details of the selected indicator in the indicator details view.
  - *Disadvantages*
    1) The trend lines and dependencies between the indicators are missing from the presentation.
    2) The details (i.e. name, value) of each indicator are not visible to the users. They can view only the details of the selected indicator.
    3) When the user selects one indicator in the dashboard, this indicator is not distinguished by the others.

- **Arc View**
  - *Advantages*
    1) The most understandable and familiar metaphor.
    2) Can aggregate all the indicators of the same area in one indicator.
    3) Easy to overview the indicators.
    4) Inform the users if the value is closed to the boundary of a colour definition in the analysis model (i.e. "how green is green for a specific indicator") for all indicators.
  - *Disadvantages*
    1) The trend lines and dependencies between the indicators are missing from the presentation.
    2) The value of each indicator is not visible.

- **Thermometer View**
  - *Advantages*
    1) Can aggregate all the indicators of the same area in one indicator.
    2) Notify the users if the value is closed to the boundary of a colour definition in the analysis model (i.e. "how green is green for a specific indicator") for all indicators.
  - *Disadvantages*
    1) Difficult to read and perceive the information.
    2) The trend lines and dependencies between the indicators are missing from the presentation.
    3) The value of each indicator is not visible.
    4) A scale in the bar of the thermometer is missing from this presentation which confuses the user.
    5) Too much information presented.

5.5. Summary

Table 5 presents the mean values for the questions where 5 point Likert scale and 10 point scale where used. These results show that the dashboard overview presentation is the most highly graded from the new presentations. Moreover, the dashboard overview presentation provides answers to questions as "What is the actual value of the indicator?" and "What are the decisions criteria for this indicator?" The current presentation is in the same level with the dashboard overview presentation.

Question	Current	Dashboard	Arc	Thermometer
In scale of 1–5, how easy is it to overview the indicators?	3.4	4.4	4	2.4
In scale of 1–5, how easy is it to interpret the results?	4.7	4.7	3.7	2.7
In scale of 1–5, how easy is it to find the detailed value of indicators?	5	4	1.4	1.4
In scale of 1–5, how easy is it to understand the metaphors used in this way of presenting the information?	4	4.7	5	3.7
In scale of 1–10, how well does this way of presentation fulfil your information needs?	7.7	6.4	5.7	3

Table 5: Results of the evaluation

We should consider, however, the bias that the interviewees could have introduced to this process. The prototypes are evaluated on paper prototypes, which did not show the full potential of the prototypes. The interviewees had no previous training and this was the first time that the interviewees were presented with these new ways of presenting indicators.

The list of questions from the second round of interviews is presented in Appendix B.

6. CONCLUSIONS

This master thesis presents an explorative case study on how can we optimize the presentation of software metrics indicators in industrial measurement systems.

Four ways of presenting the indicators are identified where only three of these prototypes are evaluated through interviews. The evaluation of the prototypes shows that the dashboard overview presentation is the best provided solution. The dashboard overview, as a space efficient presentation, offers to the user the possibility to capture the status of all indicators in a figure. At the same time, this presentation displays the required level of detailed information when the user selects an indicator.

The evaluation shows that the quality managers require more detailed information embedded on the overview solutions. Moreover, the quality managers accept and receive more positively objects they are familiar with. In addition, the research revealed that simpler ways of presenting information (arc) are perceived easier than complex ways of presenting information (thermometer). This conclusion confirms the results of another study performed by Chen and Yu [26], presented in section 2.

According to our results, during the selection of the techniques that will visualize indicators in measurement systems, the design and development team should be concerned of providing not only an overview presentation, as we did, but also a required level of detailed information. This presentation will communicate to the quality managers the status of the project in an easy understandable way.

During this study, the interviewee stated that he does not distinguish if the value of the indicator is closed to the boundary of a colour definition in the analysis model. This issue is resolved in all our prototypes presenting to the quality managers the status and the exact position of the status related to the boundaries. Another issue exposed by our research is the issue of aggregation. The study showed that it is difficult to define criteria in order to aggregate colors or indicators. Nonetheless, this issue is not in immediate relation with the presentation of software metrics indicators as it is related to the policies of the measurement system itself.

Future research in this field could improve the proposed techniques – prototypes – by including names and values of the indicators in these presentations. Furthermore, we believe it would be interesting to investigate how, more advanced visualization techniques could drive a step further the work of quality managers

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APPENDIX A – TRANSCRIPTS FROM THE FIRST ROUND OF INTERVIEWS AT THE COMPANY.

Questions
1. What is your role in the measurement program: e.g. developer or Measure System, stakeholder, measurement collector?
a. How many complete measurement system do you have?
b. Do they all present indicators?
c. Is the measurement system for a specific project?
d. Why do not you integrate all to one?
e. Can you categorize them?
2. What are your information needs that the measurement system fulfils?
a. Who is responsible for the measurement culture, the company or the quality manager?
3. How do you usually use your Measure System? Can you describe a scenario?
4. How is the information presented to you from the Measure System?
5. Can you interact with the information presented in the Measure System?
a. 3 most negative
6. Below the information quality attributes are shown in a random order. Could you distribute 100$ between the below attributes according to the importance of each in your work?
7. Is there any other quality attribute that is not included in question 7 that is important to you and why?
8. According to the previous question could you explain why are important to you?
9. Are you using colour or size encoding in your Measure System?
10. Do you think that colour encoding helps you to interpret their meaning?
a. If you use colours in your current Measure System, which one do you use?
b. Why do you use these colours? Are you based on any cognitive method?
c. Does this way of presenting indicators have limitations?
11. Could you think of other ways of presenting indicators which could address these limitations?
12. What types of outputs does the system that you are using offer?
a. Is there anything that you would add?
13. Is it possible to meet with you later and go through the indicators presentation that we found out, and evaluate them?

APPENDIX B – TRANSCRIPTS FROM THE SECOND ROUND OF INTERVIEWS AT THE COMPANY.

No.	Question
1.	Which is your role in the company? What are your information needs when using the measurement system?
2.	Can you briefly describe how you use measurement system in your work?
3.	In scale of 1–5, how easy is it to overview the indicators?

Current	Dashboard	Arc	Thermometer
1 2 3 4 5 [ ] [ ] [ ] [ ] [ ]	1 2 3 4 5 [ ] [ ] [ ] [ ] [ ]	1 2 3 4 5 [ ] [ ] [ ] [ ] [ ]	1 2 3 4 5 [ ] [ ] [ ] [ ] [ ]
Scale details: 1 – Very difficult: 2 – Difficult: 3 –Normal : 4 – Easy: 5 – Very easy			

No.	Question
4.	In scale of 1–5, how easy is it to interpret the results?

Current	Dashboard	Arc	Thermometer
1 2 3 4 5 [ ] [ ] [ ] [ ] [ ]	1 2 3 4 5 [ ] [ ] [ ] [ ] [ ]	1 2 3 4 5 [ ] [ ] [ ] [ ] [ ]	1 2 3 4 5 [ ] [ ] [ ] [ ] [ ]
Scale details: 1 – Very difficult: 2 – Difficult: 3 –Normal : 4 – Easy: 5 – Very easy			

No.	Question
5.	In scale of 1–5, how easy is it to find the detailed value of indicators?

Current	Dashboard	Arc	Thermometer
1 2 3 4 5 [ ] [ ] [ ] [ ] [ ]	1 2 3 4 5 [ ] [ ] [ ] [ ] [ ]	1 2 3 4 5 [ ] [ ] [ ] [ ] [ ]	1 2 3 4 5 [ ] [ ] [ ] [ ] [ ]
Scale details: 1 – Very difficult: 2 – Difficult: 3 –Normal : 4 – Easy: 5 – Very easy			

No.	Question
6.	In scale of 1–5, how easy is it to understand the metaphors used in this way of presenting the information?

Current	Dashboard	Arc	Thermometer
1 2 3 4 5 [ ] [ ] [ ] [ ] [ ]	1 2 3 4 5 [ ] [ ] [ ] [ ] [ ]	1 2 3 4 5 [ ] [ ] [ ] [ ] [ ]	1 2 3 4 5 [ ] [ ] [ ] [ ] [ ]
Scale details: 1 – Very difficult: 2 – Difficult: 3 –Normal : 4 – Easy: 5 – Very easy			

No.	Question
7.	Can you tell us 3 advantages that this presentation provides?

Current	Dashboard	Arc	Thermometer

No.	Question
8.	Can you tell us 3 disadvantages that this way of presenting indicators provides?

Current	Dashboard	Arc	Thermometer

No.	Question
9.	Which of your information needs each way of presenting indicators fulfills?

Current	Dashboard	Arc	Thermometer

No.	Question
10.	Do you miss anything in this way of presenting the indicators? If so, what?

Current	Dashboard	Arc	Thermometer

No.	Question
11.	What would you like to add to this way of presenting indicators?

Current	Dashboard	Arc	Thermometer

<table>
<tr><td>12.</td><td>Is there anything you would like to remove from this way of presenting information?
<table>
<tr><th>Current</th><th>Dashboard</th><th>Arc</th><th>Thermometer</th></tr>
<tr><td></td><td></td><td></td><td></td></tr>
</table></td></tr>
<tr><td>13.</td><td>How well does this way of presentation fulfil your information need (on the scale 1-10)
<table>
<tr><th>Current</th><th>Dashboard</th><th>Arc</th><th>Thermometer</th></tr>
<tr><td>1 2 3 4 5 6 7 8 9 10
[ ][ ][ ][ ] [ ][ ][ ][ ][ ][ ]</td><td>1 2 3 4 5 6 7 8 9 10
[ ][ ][ ][ ][ ][ ][ ][ ][ ] [ ]</td><td>1 2 3 4 5 6 7 8 9 10
[ ][ ][ ][ ][ ][ ][ ][ ][ ][ ]</td><td>1 2 3 4 5 6 7 8 9 10
[ ][ ][ ][ ][ ][ ][ ][ ][ ][ ]</td></tr>
<tr><td colspan="4"><u>Scale details:</u>
1- Totally insufficient; … 10- Fulfils all information needs</td></tr>
</table></td></tr>
<tr><td>14.</td><td>Can you tell which way of presentation is the best one in your opinion and why?
<table>
<tr><th>Current</th><th>Dashboard</th><th>Arc</th><th>Thermometer</th></tr>
<tr><td></td><td></td><td></td><td></td></tr>
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