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Selection and Visualization of Key Performance Indicators in Product Development

Master's Thesis in the Master's Programme Quality and Operations Management

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Division of Service Management and Logistics
CHALMERS UNIVERSITY OF TECHNOLOGY
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Abstract

The importance of performance measurement is gaining increasing importance in industries in all sectors. One of the concepts utilized to serve this purpose is the concept of key performance indicators (KPI). Theoretically, KPIs have been defined as customizable business measure utilized to visualize status and trends in an organization. In general, a KPI is a link to the business operations and the business strategy. Organizations nowadays are awash with data that can be used to measure their performance. However, a challenge is to identify which of these data provide a good indicator of the organization's performance. Another challenge is to identify the best way to visualize these key performance indicators to most effectively communicate the performance to the stakeholders.

The key performance indicators are visualized in a tool popularly known as dashboards. The purpose of the thesis is two-fold. The first is to identify what to consider when choosing actionable KPIs to communicate the performance to stakeholders in different levels of the hierarchy. This question is answered using a dashboard development framework. The framework explains how to develop the content of the dashboards considering five factors: demand, supply, fit between demand and supply, implementation and predisposition of the users.

The second purpose is to help the users understand how to develop an effective dashboard. The report provides a good read of the stages of dashboard development and explains how the author was able to develop dashboards for the organization, CEVT. Apart from explaining how to develop a good dashboard, it also explains how to enable the organization to successfully adopt and implement effective dashboards using the technology acceptance model.

Keywords: *Performance Measurement and Management, Dashboards, Data Visualization*

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Vishvajith Ramprasad
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Notations

- CEVT – China Euro Vehicle Technology
- PDQ – Product Development Quality
- R&D – Research and Development
- KPI – Key Performance Indicators
- PSS – Product and Service System
- BQM – Business Quality Manager
- TQM – Technical Quality Manager
- FMEA – Failure Mode and Effect Analysis
- PQSP – Program Quality Sufficiency Planning
- IPTV – Issues per Thousand Vehicles
- DR – Design Reviews
- QRT – Quality Reliability Testing

1 Introduction

The following chapter aims to provide a background to ease the reader into the thesis work. This is followed by the purpose of the thesis. The chapter also provides an analysis of the problem at hand and the research questions that the thesis aims to answer. Lastly, the delimitations of the thesis and the outline of the report are presented.

1.1 Background

The importance of quantitative information in monitoring the products and processes is widely acknowledged (Staron, 2012). Medium-to-large organizations rely on these measures and indicators for two-fold reasons. The first is to monitor the status of the projects. The second is to plan the long term evolution of their business (Staron et al., 2016). One of the concepts utilized to serve this purpose is the concept of KPI – Key Performance Indicators. Theoretically, KPIs have been defined as *customizable business measure utilized to visualize status and trends in an organization* (Kaplan and Norton, 1997). The KPI is in essence, a link to the business operations and the business strategy. A KPI is said to be customizable, i.e. they must be measures and indicators that can be placed in the context of the organization utilizing them (Staron et al., 2016). A good quality KPI is one which is actionable and supports the organizational goals of the company in an objective and correct manner (Staron et al., 2016). KPIs are derived from the analysis of the large amount of data that the company deals with in its day-to-day business operations. Businesses nowadays are awash with data. This quantitative data is what the businesses rely on to monitor their performance. Large strides have been made to gather and warehouse data. Businesses are heavily invested in these activities. Investments are being made on state-of-the-art data warehouses running on powerful hardware and accessed by the smartest business intelligence software.

It is now established that KPIs are designed to grab the company's attention and tell them a story about their current progress and future trends. However, many organizations have conceived that KPIs made little to no difference in their performance (Parmenter, 2010). In most cases, this is due to a fundamental misunderstanding of the use of the KPIs and the way the story is told. The millions of dollars invested in data warehouses, the most powerful hardware, and state-of-the-art business intelligence software goes down the drain if the people who utilize the data are not aware of how to make sense of this data to see their performance or how to present it in a lucid manner to decision makers (Few, 2013). The story is best communicated if it is visualized in a manner that provides more contextual information and makes more efforts to awaken the listener's senses and interests (Gelman and Unwin, 2013). Hence, the graphical representation of KPIs is of paramount importance. In addition to grabbing the listeners attention, it is also important to choose the visualization in a manner that fulfills the end users' needs to understand the data the users are trying to monitor or analyze. The best way to visualize the KPIs is in the form of dashboards. A dashboard is the face of the usage of KPIs and their supporting analytics.

CEVT is an innovation center for the Zhejiang Geely Holding Group and develops automotive technology that will meet the demands of tomorrow's global markets. They are involved in multiple vehicle development projects including platform development and complete vehicle development. These projects are held simultaneously. The Product Development Quality (PDQ) department of CEVT supports the projects in securing the product and project quality within the projects. Additionally, they also support with making sure the product reaches the customer at the right time, using the right techniques and within the assigned budget. The progress review with respect to project quality is done at various levels of the hierarchy starting from the PDQ department all the way up to the CEO of CEVT. There are three levels of meeting which take place to monitor the progress of the project and make decisions. In this thesis, the meetings are going to be called level 1, level 2 and level 3 meetings. Interestingly, the challenge CEVT currently faces is the way the progress should be reported at the meetings. The content of the meetings varies from meeting to meeting and up the hierarchy. Some KPIs do exist to track the progress. However, the KPIs exhibited are according to what the presenters deem necessary to present. The Quality KPIs are shown according to the processes which need the most attention or if any decision needs to be taken. The detail of the KPIs presented vary between the meetings and are presented in different ways by different presenters. The progress is reported using a mix of quantitative and qualitative data. Hence, there is no standard format or template of reporting the KPIs. CEVT would like to establish a standard template to visualize the KPIs and would like to have a digital dashboard which shows the same.

1.2 Purpose

The challenge identified in the reporting structure is the content of the meetings held at the different levels of hierarchy. PDQ would like an optimized and efficient meeting structure in which the information exchanged at the different meeting levels are conducive to making quick and effective decisions. The purpose here is to provide a basis for selecting actionable quality KPIs that need to be shown at the different levels of the meetings. The KPIs need to have an impact on the attendees and allow them to easily understand the progress and make effective decisions. Also, an investigation must be carried out to see if a combination of the existing KPIs were possible to be viewed to create more of an impact while visualizing the performance.

Additionally, good visual management is needed to efficiently project the information to be presented at the meetings. The information to be presented needs to be distilled down to its most basic form to provide a helicopter view of the functioning of the entire system. PDQ aims to establish effective dashboards to be used at the meetings which provide a crisp view of the functioning of the entire PDQ department. Hence the overall purpose of the thesis is to provide the basis for selecting actionable KPIs and visualizing these KPIs using dashboards for effective decision making.

1.3 Problem Analysis and Research Questions

From the information presented above, the importance of a dashboard for the PDQ department of CEVT is evident. The first challenge is to identify what content needs to be visualized on the dashboard and for which level of meetings. The situation demands to investigate the level of detail of the KPIs that need to be shown at the different levels. Stakeholders at the different levels could prefer to view details ranging from a helicopter view of all the projects to the drilled down fine details of individual projects. Therefore, two research questions are warranted to acquire the complete answer.

- *RQ1 – What to consider when choosing actionable KPIs for multilevel stakeholders?*

From the research question above, answers will be obtained as to what the content of the dashboard should be. However, this will not address the entirety of the problem. Further emphasis must be laid on the concept of data visualization. Data becomes meaningless if presented in a way that is difficult to comprehend. Hence, the second research question is formulated to understand how the identified KPIs should be visualized.

- *RQ2 – How to develop an effective dashboard for decision making?*

It is believed that the problem will be solved when the questions above are answered individually and pieced together. The combination of these answers will provide a visually intuitive dashboard that is conducive to quick and effective decision making.

1.4 Delimitations

For the purpose of retaining focus on the crux of the thesis, certain boundaries have to be imposed. The thesis work is conducted only with respect to the product development quality department within the CEVT organization. While it is ultimately aimed to extrapolate the results of this thesis to Zhejiang Geely Holding Group (The parent organization), it is to be noted that the scope of the thesis ends at the CEVT office. Further work to align the two organizations is not a part of this thesis and the results cannot be generalized to the entire Zhejiang Geely Holding Group.

The aim of this thesis is to provide a dashboard to the CEVT PDQ office. In order to achieve this, the data behind the dashboard and the contents of the dashboard will be researched upon. The data available to work with is in itself, a limitation. The dashboard prototypes have been built utilizing the available data although suggestions to acquire other data has been made where necessary. Also, the thesis work does not include executing/implementation of the dashboard in coordination with the IT team.

1.5 Thesis Outline

The thesis report starts with an introduction to the research project and elucidates the background, purpose of the research project, the research questions and the limitations (Chapter 1). It then delves into the methodology to help the readers understand how the research has been conducted (Chapter 2). This is followed by providing the readers with the theoretical knowledge which is the foundation that the research project is built on. Three main topics have been chosen which exhibits the most relevance to the thesis: *Performance Measurement and Management, Dashboards – A Performance Measurement Initiative* and *Data Visualization* (Chapter 3). The entirety of the report follows the same structure to help the readers connect the literature review to the empirical setting, results and analysis.

The empirical setting chapter (Chapter 4) begins with the introduction to the company and the current state of working of CEVT and also the product development quality department. It elaborates on the different processes used by CEVT for which the dashboards are being created. It also talks about the current state of performance management at CEVT and explains the multilevel stakeholders that are a part of this thesis. The report is then followed by the results and analysis chapter (Chapter 5) which combines the knowledge gained from the literature study, empirical setting and results from immersion, observation and interviews to suggest optimal solutions for performance measurement and dashboards. It consists of six dashboard prototypes. This is followed by a discussion chapter where the agreement between the literature study and the acquired results are discussed (Chapter 6). The report ends with conclusions to answer the research questions (Chapter 7) and suggestions for future research (Chapter 8).

2 Methodology

In this chapter, the research methods used for the thesis are presented. Initially, the research design is presented followed by the various methods in which data was gathered. The chapter ends with a discussion regarding the data analysis and the ethical considerations.

2.1 Research Design

This study employs a combination of both qualitative and quantitative data. Qualitative insights were acquired from the stakeholders to answer part of the research questions. The qualitative study needs to adapt to insights with the progress of the thesis and there is also a bigger need to see descriptive details. However, data analysis was done to design the content of the dashboard and to perform data visualization. Both kinds of data were needed to be analysed together to arrive at the solution. Hence, the study benefitted from both inductive approach as well as a deductive approach (Bryman and Bell, 2015). The deductive approach is one where observations are made based on theory, whereas the inductive approach is one where the theory is formed based on the observations (Bryman and Bell, 2015). The inductive approach was used when the qualitative data was extracted through interviews and other qualitative data gathering methods. This approach used observations and the tacit and explicitly stated knowledge to generate a theory that fit the functioning of the department.

The deductive approach was used when the dashboard was being designed. There are numerous historical research studies and tools that are available for use and a combination of these tools and knowledge were utilized to create the dashboards. The two approaches combined complemented each other to continuously generate enough knowledge to provide a good quality solution. The inductive approach allows for the observations to be tested against existing theory which has been derived using the deductive approach (Eisenhardt and Graebner, 2007). This cycle of inductive and deductive approaches allows for the development of new theory within the research area (Dubois and Gadde, 2002).

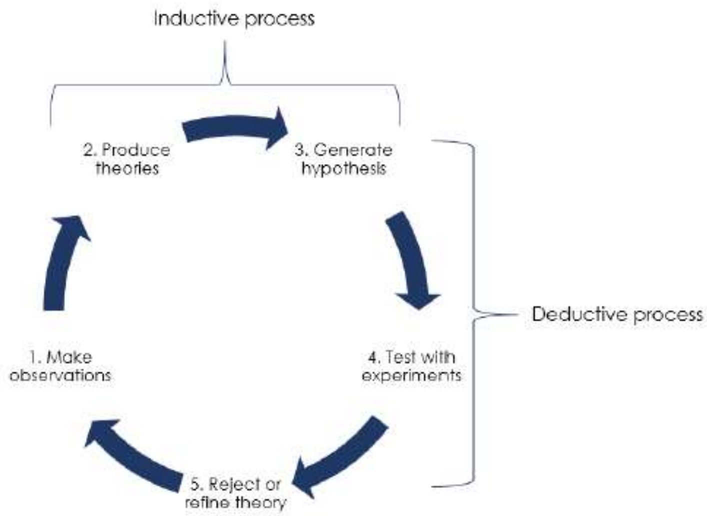


Figure 2.1 - The cycle of inductive and deductive approaches (Wahlund and Wåhlberg, 2017)

The study was conducted using a cross-functional study to include people who are within the scope of the thesis as well as stakeholders of the dashboard outside the scope of the thesis.

These people are divided into employees of the PDQ department of CEVT and employees outside the PDQ department. This was done to acquire an outside perspective of the KPIs used.

The different research methods that are used in the study are as follows:

2.2 Literature Study

The master thesis began with a literature study which laid the foundation for the entire thesis. The literature study was initially conducted in a semi-structured manner to summarize the present knowledge of the topics that the author possesses. The study then led to the authors increased understanding of the topics (Bryman and Bell, 2015). Further, the literature study led to the discovery of new areas and topics which were of relevance (Bryman and Bell, 2015). This is the traditional design of a literature study. A literature study is to be conducted in a systematic way to enhance the reliability of the study since all trustworthy empirical research is grounded in related literature (Eisenhardt and Graebner, 2007). The study was initially based on search terms such as: *Key Performance Indicators, KPIs in Product Development, Performance Measurement, Dashboards, Quality in Product Development, Quality Function Deployment and Visualization of Data.* The search terms started out to be quite generic to gain a good understanding of the related subjects. It also helped identify the gap between the academic research and current practices used at the department. This led to the literature study then being funneled down to get a deeper understanding of literature related to the gap. The search engines used for the literature study were the Chalmers Library, Science Direct, ResearchGate, and Google Scholar. The study ended at the author acquiring a fixed set of 38 research papers for further analysis that directly contributed to the improvement of the thesis.

2.3 Interviews

Interviews were held with a number of employees to get a wide variety of information to be able to answer the research questions. A selective sampling method was used to find relevant people to include in this study (Bryman and Bell, 2015). A selective sampling method aims to select people who are of direct interest to the formulated research questions. More people to be included were discovered during the progress of the research study (Bryman and Bell, 2015). As explained before, the interviewees consisted of two sets of people: 1. Stakeholders within the quality organization 2. Stakeholders outside the quality organization. Interviewees were carefully selected from the population keeping in mind the three levels of meetings that the PDQ reports at. In total, sixteen interviews were conducted with people from the different levels of the hierarchy. The interviewees consisted of the senior vice president of Quality, vice president of PDQ, three business quality managers, and six technical quality managers as interviewees from within the PDQ organization. However, the end users also consisted of users from outside the organization and were interviewed to gain an outside perspective of how PDQ must view performance measurement. The interviewees consisted of two managers, two process leaders, and a system engineer. This sample of interviewees was instrumental in providing details at a system level as well as details at the granular levels of the processes measured. The duration of all the interviews ranged from 45-90 minutes and all the interviews were conducted in person.

The purpose of the initial interviews was to talk to the potential users of the dashboard and understand their perception of performance measurement and management. The interviews also uncovered details of how CEVT utilizes their KPIs and their insights on what the KPIs should indicate. The interviews also included an exercise for the interviewees to perform allowed the employees to rate the importance of the KPIs as they view it. The individual interviews were of a semi-structured nature to allow free flow of thought (Bryman and Bell, 2015). Follow-up questions were asked based on their responses and based on the varieties of answers expected/received from other interviewees. The questions were formulated based on the literature study and the research questions used. Interviews were transcribed and recorded to avoid loss of information. Analysis of the data was done parallelly with the interviews and will be done for different levels one after the other.

2.4 Focus Group Studies

Apart from the literature study and interviews, the stakeholders were also made to do an exercise which determines how important they think the KPIs being investigated are. This was also intended to see at what point in the project, the KPIs are used, to what level they are escalated in the hierarchy and to investigate if there is a relationship between the KPIs. The KPIs were categorized into “Very Important”, “Important” and “Irrelevant to the meeting”.

Another exercise was conducted in a focus group where a relationship study was presented to the group and the participants were made to discuss with regards to how the different KPIs utilized by the quality department relate to one another. The results of this focus group discussion have been presented in the results and analysis chapter of the report (Chapter 5).

2.5 Data Analysis

Data analysis was done with the combination of qualitative data obtained from interviews and literature study and the quantitative data obtained from observation and immersion into the processes. As new data was constantly collected during the thesis, data analysis was done on a continuous basis and theories were formulated and tested through the thesis. It was also iteratively performed with feedback from the stakeholders at CEVT. This is in line with the inductive nature of the study where the data collected affects how the study will proceed further.

2.6 Ethical Considerations

In a research project, four principles must be considered. They are: Lack of Informed Consent, Harm to Participants, Invasion of Privacy and Deception (Bryman and Bell, 2015). These principles were considered at every step of the thesis work to ensure that the research work is ethical. Interviewees were well informed of the intentions with the organization and the nature of the work being undertaken. They were informed that the information obtained from them will be published and that they have control over the content that is published. The interviewees were given the chance to withdraw participation in the thesis at any time in the thesis if they felt discomfort with sharing the information. Anonymity was provided if the interviewee wished. Possibility of reviewing the information was provided before the information was published. Interviews were recorded only after obtaining consent.

3 Theory

This chapter aims to introduce the reader to the literature relevant to the thesis. This section provides the foundation on which the rest of the report is built on. It introduces the reader to the concepts of performance measurement and management, dashboards and data visualization.

3.1 Performance Measurement and Management

The last 20 years have seen an increasing interest in the concept of performance measurement (Neely and Bourne, 2000). Organizations throughout the world are reengineering their measurement systems. Performance measures appeared in the early 1900s as control mechanisms that could support budgeting and planning processes in large organizations like Du Point and General Motors (Bourne et al., 2018). These performance measures were instrumental in supporting the development of new organizational processes (Johnson, 1981). One of the most popular performance measurement and management framework is the Balanced Scorecard (Kaplan and Norton, 1997). The success of this framework is owed to its capability to align strategic objectives with performance measures and action plans (Bourne et al., 2018) and to connect financial and non-financial indicators (Ittner et al., 2003). Hence, a good performance measurement system is designed to do just that.

Performance measurement is designed to cascade down an organization to attempt to ensure that units, teams, and individuals respond and contribute to the same corporate objectives along with ensuring an appropriate level of accountability (Kolehmainen, 2010). This needs a 'golden thread' across the organizational levels leading to tight coupling between units (Bourne et al., 2018). This raised the question – "How do we select a balanced and integrated set of measures?" (Neely and Bourne, 2000). People started talking about measures of shareholder value, economic profit, customer satisfaction, employee satisfaction, internal operations performance, intellectual capital, and intangible assets to answer this question (Neely and Bourne, 2000). It was soon realized that deciding what to measure was of paramount importance. It was also discovered that this process forced the management team to be very explicit with the language they use when it comes to performance measurement. It was no longer enough to say, "We want satisfied customers and employees". The meaning of happy customers needed to be defined to decide how to measure if the customers are satisfied (Neely and Bourne, 2000).

The measures, once defined in a lucid manner, offer an excellent way of achieving organizational goals and alignment (Neely and Bourne, 2000). Well defined measures which are most often linked to financial systems gave a clarity as to what is most important to the organizations (Neely and Bourne, 2000). Apart from the aspect of what to measure, there is another aspect which makes up a good performance measurement system – Implementation Process (Neely and Bourne, 2000). Implementation of the measurement systems must be given equal importance since, without a good implementation process, the established measurement system will fail to have an impact (Neely and Bourne, 2000). Unfortunately, it has been observed that the easiest part of the performance measurement system is the design of what to measure. Many performance measurement systems have never seen the light of the day due to inappropriate implementation or failure to implement altogether. There are numerous other reasons for this, but they can be effectively categorized into two different categories – Inappropriate Design of Measurement Systems and Failure to Implement. The following sections go into details of the two categories of failure. The failures were considered to be an important part of the literature study to help the research project avoid making the same mistakes that have been previously made by the organizations who undertook the performance measurement initiative.

3.1.1 Why Performance Measurement Initiatives Fail

3.1.1.1 Inappropriate Design of Measurement Systems

The key to designing an effective measurement system is to not directly jump into discovering what the organization should measure, but by looking into the organization's success map (Neely and Bourne, 2000). A success map is a cause and effect diagram that elaborates an organizations strategy and its business operations. It elucidates the actions that a manager can perform and the power that managers have in influencing the performance of the organization (Neely and Bourne, 2000). For example, in a manufacturing environment, the manager can perform two actions to improve the performance of the manufacturing line, one is to reduce lead times, and another is to improve stock control. Both these actions improve delivery performance which improves the operational efficiency of the organization. Once this success map is laid out in plain sight, it becomes easy for the managers to identify the right measures of performance. This method is far better than just brainstorming on what should be measured and creating a process to obtain these measures (Neely and Bourne, 2000). The latter method loses ties to the organizational strategy and when the employees view these measures, they fail to understand the logic behind it and start questioning the validity of the measures. They refuse to then adhere to the practice of improving the measures, thereby relapsing into the previous state of having an inappropriate or no measurement system (Neely and Bourne, 2000).

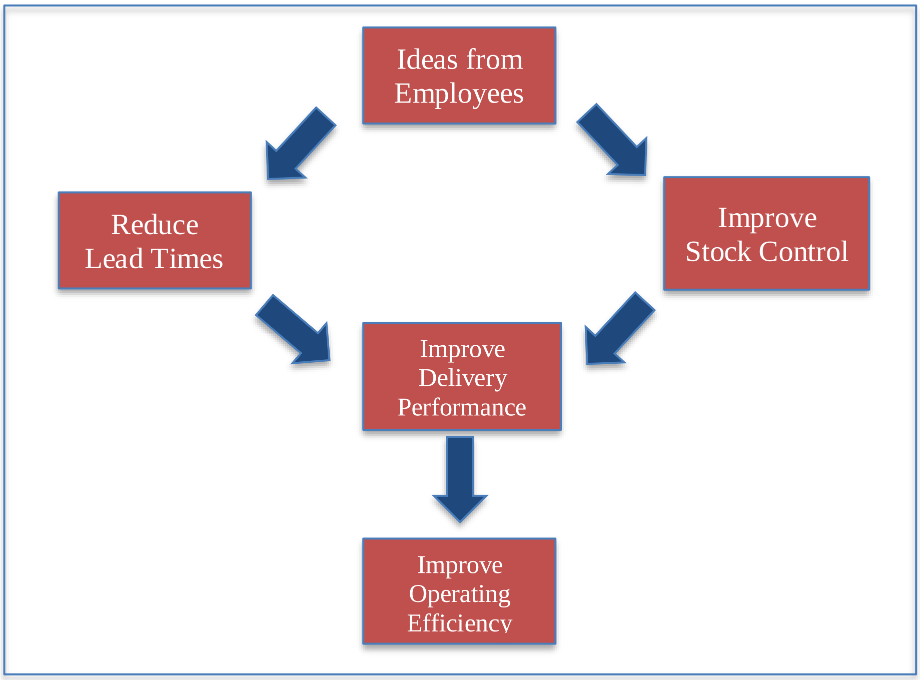


Figure 3.1 - Sample Success Map (Neely and Bourne, 2000)

3.1.1.2 Failure to Implement

The second reason for the failure of performance measurement systems is the implementation failure of the measures even if they have been successfully identified. These failures have been categorized mainly due to three reasons – political, infrastructural and focus (Neely and Bourne, 2000). In a lot of cases, the measurement system is not viewed as an improvement or driving method. It is perceived to be purely political. There are examples of managers using dashboards to compete with other managers and to illustrate why they are failing to produce results. It becomes a number game since it is not used with the right intentions. The second reason is simply due to the lack of infrastructure within the company. In most cases, the company has all the data required to measure in some form or the other. However, the data is found in multiple places with different people being in charge of it. The data is held in multiple databases and stored in inconsistent formats. It becomes difficult to gather the information, see the connection and the big picture (Neely and Bourne, 2000). Lastly, measurement systems fail to perform due to the amount of time and resources an organization needs to put in to establish the systems. Individuals get frustrated with the implementation process. Also, sometimes the organization's priorities change, and efforts are no longer devoted to implementing the measurement system (Neely and Bourne, 2000).

3.2 Dashboards – A Performance Measurement Initiative

The organizations of today are driven largely by the advancements in information technology. This provides them with both a boon and a bane of working with massive amounts of data. Managers are more often than not, overwhelmed with reports and information from different parts of the organization. The information comes in varying formats and is very inconsistent since they are churned out from multiple sources such as individuals, Enterprise Resource Planning (ERP) Systems, business intelligence software and performance scorecards (Yigitbasioglu and Velcu, 2012). These poorly designed reports often distract the decision makers attention or fail to secure their attention to the actual problem at hand.

Performance dashboards have been seen to be increasingly important to overcome the information overload experienced by combining applications such as strategy maps, scorecards, and business intelligence into one solution (Yigitbasioglu and Velcu, 2012). Ideally, a dashboard is supposed to collect, summarize and present the aforementioned information from different sources such as ERP, BI, and individuals on one platform so that the decision maker can see at once how the organization is performing. Few (2006) describes a dashboard as "*A visual display of the most important information needed to achieve one or more objectives, consolidated and arranged on a single screen so the information can be monitored at a glance*." A dashboard shows only the tip of the iceberg, i.e. what the user sees first from the data behind it. However, if a cause for concern is found at first glance, it allows zooming in on the information that needs to be more closely examined (Matheus et al., 2018).

Pauwels et al. (2009) distinguish between two types of dashboard features: functional features and visual features. Functional features describe what the dashboard can do, and visual features refer to the principles of data visualization, i.e. how effectively information is collected and visualized for the decision maker. It is evident that a dashboard needs its functional features to fit with the purpose of the dashboard. A poor fit will cause poor decisions to be taken due to the fact that the dashboard exhibited only partial information. Poor visualization will also turn out to be more than just an inconvenience to the decision maker. It could confuse and distract the user from viewing the underlying problem (Pauwels et al., 2009).

3.2.1 Purpose and Benefits

Human processing capacities are limited and dashboards have made data-driven analytical decision making possible. Organizations that have understood the analytical capabilities to be an important element of their strategy perform better than their competitors since they have more information to base their decisions on (Pauwels et al., 2009). They know what products the customers want, their willingness-to-pay for the products, the quantity of purchase and the trigger that would favor their purchase (Davenport and Harris, 2007). The effectiveness of a dashboard can be judged based on five potential benefits that they provide to the organization:

- The sharing of metrics is a necessity for establishing the organization's culture (Gulati and Oldroyd, 2005). Interdisciplinary design of dashboards provides an opportunity for developing a holistic and creative outlook towards organizational issues (Wind, 2005)

- An effective dashboard provides the mindset of recognizing good organization performance, diagnosing poor performance and evaluating the different options available to solve a business problem (Pauwels et al., 2009). The dashboard must be able to visualize the current status against the business plan, and also a forecast of the options available to be implemented (Pauwels et al., 2009).

- Enabler of organizational learning. It was found that during the usage of the metrics, causalities were identified which provided learning opportunities for the users (Clark et al., 2006).

- The dashboard must effectively increase the future profitability of the organization (Eckerson, 2010)

- The interdisciplinary nature of the dashboard allows for decision making using consensus building (Pauwels et al., 2009).

A dashboard achieves integration of different departments in three ways (Pauwels et al., 2009):

- *Data*: Comprehending the organization's performance needs information and data from multiple sources of the organization at different levels of maturity levels and covering multiple time periods. The dashboard can combine these aspects on one common framework.

- *Processes*: A dashboard helps management connect the inputs of the organization like expenditures to build the product to the performance of the product in the market and ultimately to its financial performance such as profits, etc. In this way, management can bridge the gap between internal affairs and external performance.

- *Viewpoints*: A dashboard helps the different department speak the same language. The different employees working in different departments view the organization's performance in the same light.

3.2.2 Risks

Along with the benefits, dashboards also come with their share of risks. Even with a properly designed dashboard, the detection of strange patterns is useless if there are no systems in place to further investigate these patterns resulting from the data science analysis (Matheus et al., 2018). One of the main risks of a dashboard is misinterpretation of information, which could lead to incorrect conclusions and inappropriate decision making (Matheus et al., 2018). A dashboard could also hinder transparency and accountability if it is not designed properly. The case of information overload especially results in a reduction of transparency and accountability (Mattheus and Janssen, 2013).

Developing a dashboard is expensive. It is heavy on resource consumption and the data scientists are not abundant in number (Matheus et al., 2018). There is also a risk of reduction in quality of the dashboard if the data originates from multiple sources from different departments (Matheus et al., 2018). Sometimes, it is found that dashboards are not used by managers due to the difficulty of accepting new technologies and possible loss of decision-making powers (Matheus et al., 2018). Hence, an organization must be conscious of all the risks associated with dashboards so that they can parallelly build the discipline required for the efficient usage of dashboards before they create one.

3.2.3 Dashboard Development Stages

Dashboard development can be delineated in five different stages. The framework mentioned below include not just the customers, but also the financial managers. Hence, the framework provides a holistic perspective on dashboard management and effectively combines internal processes and external affairs (Pauwels et al., 2009). The five stages are:

Stage I: Selecting the Key Metrics

Ambler (2003) puts forth two different approaches to the selection of metrics: General and Tailored. The general metrics include the few metrics which can be applied to virtually every setting and includes the benefit of comparability. It enables benchmarking across business units, firms, industries and time periods. He puts forth three profit and loss measures (profit, revenue, and marketing expenditure) and seven brand equity measures (awareness, preference, brand loyalty, customer thoughts, feelings, market share, availability, and relative price). Other research articles have identified metrics which resonates with his arguments.

The second approach to metric selection is the tailored method. The tailored methods emphasized that each business unit/company has its own perspective on strategy and positioning and requires several metrics to track its performance towards their specific objectives (Ambler, 2003). It requires high-level communication throughout the organization to determine the important metrics for the business (Pauwels et al., 2009). This communication must happen between three kinds of people: a) Those who will use the system b) Those that will be measured by it and c) Those that will use the dashboard to make decisions (Pauwels et al., 2009). This fulfills the requirements of cross-functional development of the dashboard. This also leads to cross-functional collaboration and research. The disadvantages that come with this approach is the sheer time and resources it will take to develop the dashboard. It might also lead to the generation of more than an adequate number of metrics since different people who use different metrics will push for the ones they understand (Pauwels et al., 2009). This will lead to unnecessary complication of the dashboard, thereby reducing the acceptability and prevent usage of the dashboard (Clark et al., 2006). This disadvantage can only be offset by the involvement of top management in the development and also only looking at the leading indicators of performance (Clark et al., 2006).

Stage II: Populating the Dashboard with Data

The logical way to populate the dashboard is with the metrics already available to be used. This will result in low cost and discover useful metrics and appropriate combination of the metrics. However, holding on for longer to develop better metrics might be more advantageous in the long term (Pauwels et al., 2009). For example, recent development in performance measurement discovers that companies are ditching financial evaluation of metrics and replacing them with metrics that revolve more around consumers. This seems to provide more actionable insights (Pauwels et al., 2009).

Certain firms have a massive amount of data that can be measured with numerous metrics obtained from multiple sources. Another problem faced is how frequently new data gets stored in the database. Some organizations get massive amounts of data on a daily basis. Some of the data collected will be more important for the metrics than the others. This data must be considered and given priorities to decide what goes on the dashboard (Pauwels et al., 2009).

Stage III: Establishing Relationships Between the Dashboard Items

This stage involves the identification of the underlying relationship between the KPIs. How well this stage is managed determines if the dashboard is just a presentation of the available information or if the dashboard leads to a deeper understanding of the business and the decision support system (Pauwels et al., 2009). Simply putting on the available metrics on the dashboard cannot address the cause-and-effect relationships between the data that could improve the performance of the business. It also does not allow to experiment with the causal relationships between data that could deepen the understanding of the metrics (Wyner, 2004).

The relationship between dashboard metrics and performance is characterized by indirect effects, dual causality and performance feedback (Dekimpe and Hanssens, 1999). A dynamic system approach, therefore, is a more logical approach to discover these relationships. Multiple models exist to determine these relationships, namely, logit choice models, structural equation models, linkage analysis and decision calculus (Pauwels et al., 2009). As more data gets unearthed, it will be more possible to test the inherent assumptions that the managers use to make business decisions. Sometimes, the disagreement between the management team with regards to these assumptions could prove to be the best areas of research to investigate the relationship between the metrics. Data collection and experimentation can be carried out to better understand these relationships (Pauwels et al., 2009).

Stage IV: Forecasting and Scenarios

Stage IV involves discovering the what-if analysis as a way for managers to evaluate all the options available and take a well-informed decision. This stage can help with scenario planning and budget setting (Pauwels et al., 2009). For example, if a service firm could identify metrics that help them predict the service demand accurately or even as an approximate, they can arrange the resources well in advance to fulfill the demand (Pauwels et al., 2009). This potential to do wonders goes unrealized in most situations since most firms only focus on metrics that explain the current status of operations (Pauwels et al., 2009).

Stage V: Connecting to Financial Consequences

This stage connects the activities involved at the beginning of the process to the end result which is measured mostly in terms of financial consequences. For example, in a product-based firm, this stage is when the firm connects the marketing expenditure to the sales results and the financial consequences for the firm. This links the marketing to the value created for the stakeholder and could help align the corporate goals, investors perspective, and the end customer. Hence, the importance of this stage lies in its ability to align the metrics with a view on financial consequences as well as customer satisfaction since customers are the key generators of cash flow.

3.2.4 Adoption and Success of Dashboards – The Framework

This section consists of a framework for the adoption and success of dashboards. The framework is built on the existing Decision Support Systems (DSS) framework. Pauwels et al., (2009) proposes that the adoption and success of dashboard is driven by five main factors as shown in figure 3.2: Demand, Supply (e.g., metrics availability), the fit between demand and supply, implementation process and the predisposition of users.

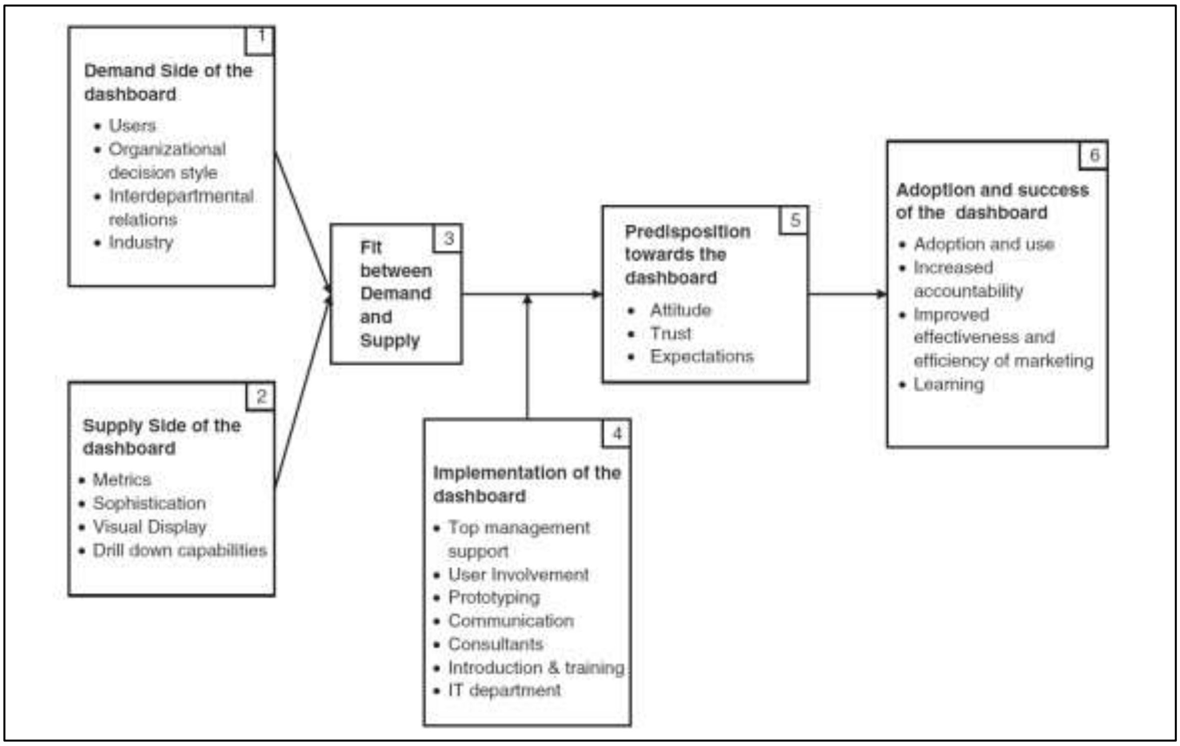


Figure 3.2: Framework for the Adoption and Success of Dashboards (Pauwels et al., (2009))

Demand:

The most important factors of demand as shown in box 1 in figure 3.2 are:

- *Users*: At most times, the users of the dashboard are senior management. However, the dashboards can be used by top management, finance department, R&D, production, purchasing, etc. Sometimes, a combination of above are used in case it is a project-based team.

- *Organizational Decision Style*: Every firm has its own way of working and decision making. The same dashboard cannot be successful both in companies where analytical data-driven decisions are made and in companies where decisions are made based on experience and gut feeling.

- *Interdepartmental Relations*: If the firm works with departments which coordinate well with each other and have the same goal in mind, then a dashboard will be used for the common purpose of achieving that goal. In firms where the interdepartmental relations are not very good, the dashboard could be misused by the individual departments to benefit themselves

- *Industry*: Different industries view and use dashboards is a unique way as previously stated. Some use a generic approach to dashboards and its metrics. Some use a tailored approach that is specific to their firm or business units. The goals of the individual industry, firm and business units could also vary from each other.

Supply:

The factors driving the supply side of dashboards as shown in box 2 are:

- *Metrics:* The availability of data and metrics drives the content of the dashboards. In most cases, more the data available to analyze, more concrete is the evidence presented on the dashboard.

- *Sophistication:* Some dashboards only present the as-is condition of the organization. Some dashboards present the what-if analysis of the different decisions that the organization can take. The type of dashboard depends on the demand of the organization

- *Visual Display:* There are numerous ways to present information, words, bar charts, pie charts, animations, etc. The users need to be comfortable with reading the dashboard. It needs to be user-intuitive. Some dashboards go overboard to show information in ways that the human brain cannot comprehend. Information is best communicated when it is presented in a lucid manner with a good summary, good visual indicators, and a good presentation.

- *Drill down Capabilities:* A dashboard could be designed to show the information on a system level. However, well-designed dashboards also have the capability to drill down the information to its granular form. A good dashboard is one which is understood and used by different managerial levels of the organization.

Fit between Demand and Supply (Box 3):

The fit between demand and supply is critical for the success of a dashboard. The information presented on the dashboard must be relevant for the users and the decision makers and must make it conducive for the decision makers to take the right decisions. The information presented must be aligned with the strategic orientation of the company. If the company has a lot of options that could drastically change outcomes, a dashboard that allows the what-if analysis is more useful, the as-is dashboard will be of no use. If the company is analytical, the dashboard must be data-driven. In this sense, the fit between demands of a dashboard and the supply must align.

Implementation (Box 4):

As previously stated, a performance measurement system will fail if the implementation is a failure. There are a number of key success factors for a successful dashboard. It includes top management support and user involvement in the development of the dashboard. The competence of the IT department is also important. A supply-driven dashboard will not be relevant to the demands of the users. A demand-driven dashboard could be tough to implement. Sufficient trade-offs must be done to ensure a fit between demand and supply. Implementation must include prototyping, testing, and continuous feedback and updates. There could be multiple prototyping cycles with cross-functional testers. This will allow the IT team to better understand the requirements. Time, as well as budget, should be sufficiently allocated to implement a successful dashboard since they are two of the biggest risks of killing implementation.

Predisposition of the Users (Box 5):

A dashboard with a good fit between demand and supply must elicit a positive response from its users with the following key elements:

- *Attitude:* Two main drivers that elicit a positive response from its users are its perceived usefulness and the ease of use. This is the Technology Acceptance Model (Avlontis and Panagopoulos, 2005). Decision makers must feel like they can take better decisions if they use the dashboard.

- *Trust:* Decision makers need to ensure that the dashboard is trustworthy and that the system cannot be cheated. Sufficient systems must be in place to drill down to investigate strange patterns. The dashboard must also not impede the autonomy of the employees.

- *Expectations Management:* A dashboard will not be without initial bugs and problems. Low expectations will reduce acceptance. High expectations will cause dissatisfaction. Expectations must be managed.

The Adoption and Success of Dashboard (Box 6):

This box is dependent on the fulfillment of the other five boxes. The adoption and success of a dashboard can be measured on four dimensions:

- *Adoption and Use:* The dashboard must be used by multiple departments and a congruence must be obtained. The dashboard must go through multiple iterations using cross-functional testers so that it is accepted, and the expectations can be managed, and the testers can ensure that the dashboard fits the purpose that they would like to use it for.

- *Increased Accountability:* The firm must be able to accept accountability. This is one of the key uses of a dashboard.

- *Improved Effectiveness and Efficiency*: The different departments must utilize the dashboard to better monitor and better deploy their efforts to obtain an increase in effectiveness and efficiency

- *Learning*: Dashboards are not just made for decision making. They are also designed to enhance learning and cross-functional knowledge transfer. It must also encourage implicit learning with individuals who uses the dashboard.

3.3 Data Visualization

In the current state of affairs in the industry, the amount of data generated and accessible is massive. This is when quality visualization of data becomes utmost important in order to enable effective interpretation of the data, particularly for decision-makers who do not have a statistical background (Duke et. al, 2015). Adequate graphic design is deemed critical in the creation of graphs that efficiently and effectively translates the important messages in the data. The human brain is good at pattern recognition. Hence, really powerful techniques must be utilized that renders the key messages of the graph through patterns (Duke et. al, 2015). There are numerous tools at present which can be used to visualize this pattern: bar chart, pie, chart, stacked column charts, box plots, scatter plot, etc.

The question of how to efficiently map the decision maker's requirements of the dashboard (Demand) to the data available (Supply) utilizing appropriate supporting visualization (Fit) is studied by understanding the below three topics.

3.3.1 Graphical Practice

Tufte (2001) says, "Of all methods for analyzing and communicating statistical information, well-designed graphics are usually the simplest and at the same time the most powerful". Cleveland (1994) further elucidates Tufte's words. He says "When a graph is constructed, information is encoded. The visual decoding of this encoded information is *graphical perception*. The decoding is the vital link…no matter how ingenious the encoding and no matter how technologically impressive the production, a graph is a failure if the visual decoding fails".

Nine simple practices are highlighted by Tufte (2001) with regards to graphical excellence. He says that graphical displays should:

- Show the data
- Enable the viewer to focus on the core substance rather than the methodology, graphic design, the technology behind the visualization and pretty much everything else.
- Avoid distortion of what the data is supposed to communicate
- Present a lot of numbers in limited space
- Make large data sets coherent
- Encourage the eye of the viewer to compare multiple aspects of the data
- Allow for drill-down capabilities of the data. The display must allow the data to be viewed at a holistic level as well as provide the capabilities to view the data in a granular form.
- Serve a clear purpose: description, exploration, tabulation or decoration
- Be closely aligned with the statistical and verbal description of the data set

The best graphical practice also ensures that the data that the graphs represent are reliable. A graph is only as good as the data that goes into it (Tufte, 2001). Information that is incorrectly extracted is incorrectly retained and visualized. In this case, a person who has viewed data visualization and carefully investigated the data behind it will only gain a partial understanding of the picture. This partial understanding will soon be erased from memory due to difficulty in retention. When the data is correct and has been visualized correctly, the graphic will leave a distinct impression with the ability to be retained in the mind for an adequate amount of time. Such is the power of graphics (Tufte, 2001).

3.3.1.1 Data Graphic Distortion

When the graphical representation of the data is incorrect with the numerical representation, it leads to what is known as 'Data Graphic Distortion' (Tufte, 2001). Misperception and miscommunication are rampant in statistical graphics. However, a data graphic designer cannot design a graphic for every perceiver in each context. Hence, the use of tables. Tables outperform graphics in cases where the data set is small (Tufte, 2001). The power of data graphics is obvious only in the case of large data sets. Another way to bypass this issue is to ensure uniformity in the use of the graphics. Hence, two principles can be considered while trying to avoid data graphic distortion.

- The representation of numbers should be directly proportional to the data quantity represented.
- Lucid labeling of the data and events needs to be used to avoid graphic distortion

3.3.2 Information Visualization versus Statistical Graphics

When it comes to visualization of data, there are usually two schools of thoughts that divide researchers, information visualization and statistical graphics (Gelman and Unwin, 2013). Statistical graphics are prominent within the academic/professional bubble within statistics. The use of box plots, scatter plots, line plots, etc. are very common. However, outside of statistics, statistical principles are ignored and infographics, also known as information visualization or InfoVis, are used. They provide information in a visually pleasing way, some even use videos and sounds to bring forth the data. The two schools of thought have some inherent contradictions that have to be kept in mind to combine their principles in an effective manner.

Statisticians and data analysts argue that an effective and precise way of representing data, in either the raw form, statistical form or analysed model form is what is important (Gelman and Unwin, 2013). They further go on to say that a correct comparison needs to be provided to the viewers. Numbers do not make much sense on their own, hence they need to be complemented by graphics. These graphics allow the viewers to arrive at their own conclusions and possibly view more (Gelman and Unwin, 2013). On the other hand, proponents of information visualization argue that what is more important is grabbing the viewer's attention and providing them the information like a story. It is based on the human mind and its ability to grab patterns. When they represent data, they do so in a manner that provides the viewer with more context, hence making it easier for them to understand the numbers. Information provided in this way will also awaken the viewer's senses making it easier to process and retain the information (Gelman and Unwin, 2013).

Despite the inherent contradictions, both schools of thought have a relevant take on data visualization and the most effective way to visualize the data would be to combine the two approaches. If designers could comprehend the goals of statistical graphics and utilize the principles while designing information visualization, the combined effect of aesthetics and functionality will accurately deliver the information behind the data.

3.4 Technology Acceptance Model

The purpose of the thesis is to provide the basis for selecting actionable KPIs and visualizing these KPIs using dashboards for effective decision making. In order to provide an end solution that is satisfactory to the customer, a model known as the Technology Acceptance Model has been used (Davis,1987). The model is utilized in the industry with two-fold objectives, it improves the dashboard designer's understanding of the user acceptance process, providing theoretical insights into a successful design of the dashboard that is needed in order for the organization to improve by using it. The second objective is that the model allows the designer to evaluate the proposed new dashboard before the implementation of the actual dashboard (Davis,1987). Applying this model would require the designer to demonstrate prototypes to the users of the system and measure their interest in using the proposed system. Such testing could provide the designer with insights into the probability of the success of the proposed system early in the development phase (Davis,1987).

A figure elucidating the TAM is presented below. According to the model, a potential user's attitude towards using the proposed system is a direct indicator of whether the user will actually use the system.

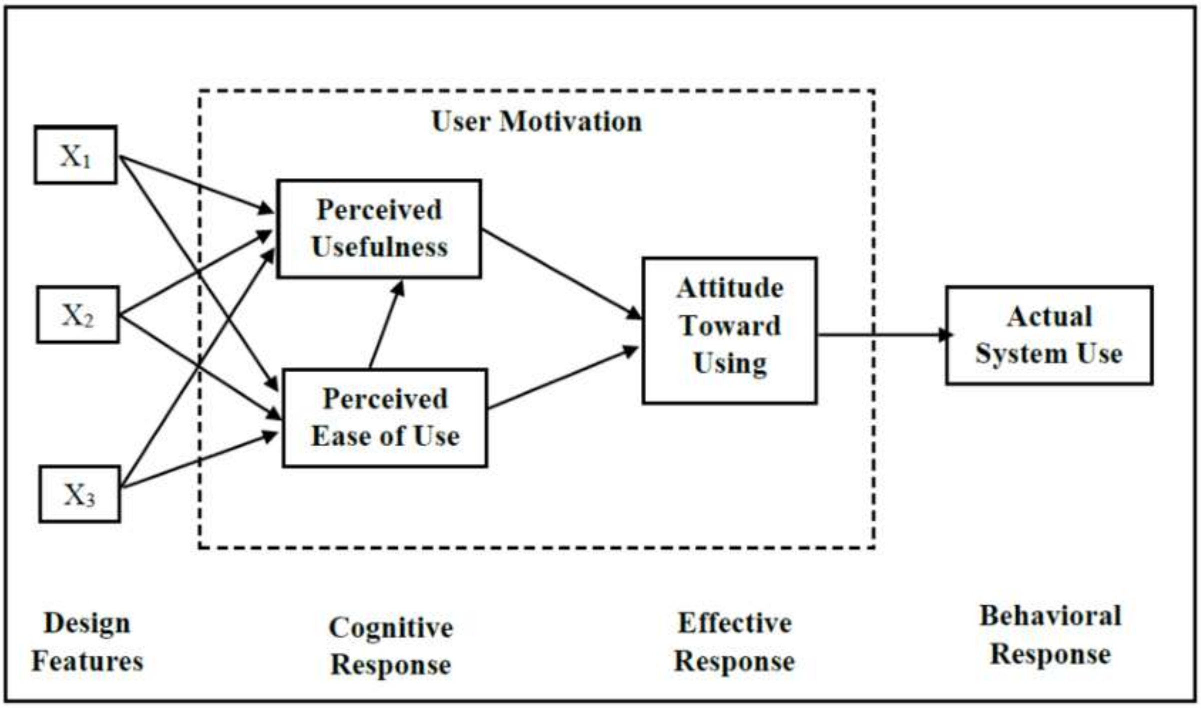


Figure 3.3: Technology Acceptance Model (Davis, 1987)

The attitude towards using the system, however, is a function of two other factors: Perceived Usefulness and Perceived Ease of Use. Perceived usefulness can be defined as "The degree to which an individual believes that using a particular system would enhance his/her job performance". Perceived ease of use can be defined as "the degree to which an individual believes that using the particular system would be free of physical and mental effort" (Davis,1987). As seen in the diagram, the perceived ease of use has a causal effect on the perceived usefulness.

The reason for perceived ease of use having a causal effect on the perceived usefulness can be explained by the fact that all else being equal, a system that is easy to use will cause the user to perform better at his/her job (Davis,1987). If the user becomes more productive upon the use of a system due to its ease of use, then the user becomes more productive overall. Hence, the causal relationship between the two aspects. What is also interesting to note is that the design features have no direct effect on attitude or behavior. However, design features of the system will directly affect the perceived usefulness and perceived ease of use which in turn directly affects the attitude of the user towards the system.

The Technology Acceptance Model has been used throughout the thesis to ensure effective delivery of the dashboards to the quality department. It was also utilized to identify the perceived usefulness and perceived ease of use at the end of the thesis to gain feedback and also to ensure a smooth implementation of the dashboard among the employees of the quality department.

4 Empirical Setting

4.1 China Euro Vehicle Technology

China Euro Vehicle Technology (CEVT) is a vehicle development center owned by Zhejiang Geely Holding Group which also owns the Volvo Cars and Lynk and Co brands along with other brands such as Polestar, Proton, Lotus, London Electric Vehicle Company and YuanCheng Auto. CEVT is used as the innovation center for them. CEVT is instrumental in developing both architecture and complete vehicles for the group. They are the developers of the famous Compact Modular Architecture (CMA).

CEVT consists of several functional departments throughout the organization. For the purpose of the thesis, it is important to know how the R&D teams are split in vehicle development projects. In a project, the R&D teams are split into units like Chassis, Body & Exterior, Interior, Electrical, etc. These units are further split into Product and Service Systems (Abbreviated as PSS) and the PSS are further divided into Function Groups. The thesis is being conducted at the Product Development Quality (PDQ) department of CEVT which collaborates with the R&D department, hence the content of this thesis will revolve around these two departments with particular focus on the functioning of the PDQ department.

4.2 Product Development Quality

The PDQ department of CEVT currently supports the product development processes by ensuring the quality of the products developed. The PDQ team consists of the Vice President of Product Development Quality, Business Quality Managers and Technical Quality Managers. Apart from ensuring the quality of the products, PDQ also supports the project managers in delivering their projects to the customer on time, using the right techniques and within the assigned cost. To enable this, the PDQ uses several processes to ensure both project and product quality. Hence, these processes are divided into project quality management and product quality management. Some of the processes are:

- Product Quality:
    - Failure Mode and Effect Analysis (FMEA)
    - Product Quality Sufficiency Process (PQSP)
    - Quality Reliability Testing (QRT)
    - Design Review (DR)
    - Virtual/Product Quality Readiness Review (V/PQRR)
    - Geely/Lynk and Co Customer Product Audit (GCPA/LCPA)
    - Deviation Management
    - Function Maturity
    - System Safety

- Project Quality:
    - Milestone and Gateway Review
    - Lessons Learned in Project
    - Project Quality Target
    - Risk Management

These processes are utilized in different ways at PDQ. Some of the processes are owned and executed by the PDQ. Some of the processes are only executed by the PDQ. Some of the processes are reviews of the work done by the product development engineers (R&D).

4.3 Performance Measurement and Management at CEVT

At CEVT, weekly meetings are conducted to report the performance of the project as well as product quality progress. Presentations are held by the different business quality managers (BQM) and technical quality managers (TQM) to report on the quality concerns. The progress is mostly reported on meetings held at the end of the week with a flexible agenda. This meeting shall be called the level 3 meeting. The agenda is set according to the project teams which are expected to present their progress. The product and project quality are measured by different key performance indicators established by the PDQ to measure the processes listed above. The reporters of the meeting communicate the progress of the project using these KPIs to the rest of the team and the decision makers.

However, beyond the aforementioned level of meeting, within the CEVT organization, there are two more levels of meetings. These meetings are held at the different levels of the hierarchy to report the performance of the projects undertaken by CEVT. PDQ participates in these meetings to report their performance in all the projects. The level of technical details keeps reducing up the hierarchy and more business level KPIs are reported and high-level decisions are taken. The meetings are:

- Level 2 Meetings – These meetings are attended by directors of the different units of the R&D teams to discuss the project progress. Milestone and Gateway review meetings are held at this level. Issues encountered by the different units are discussed. Issues which could not be solved at the level 3 meetings are escalated to this meeting. In certain cases, recommendations for solving issues need to be made at this level before taking the recommendation to the level 1 meeting for a decision.

- Level 1 Meetings – This meeting is attended by the executives of the different units and includes the CEO of CEVT. Milestone and gateway reviews are made, and high-level decisions are taken at this level. Issues encountered which could not be resolved at the level 2 meetings are escalated to this meeting. Absolutely critical matters which impact the business are discussed at this level.

The content of the meetings varies from meeting to meeting and up the hierarchy. The KPIs exhibited are according to what the presenters deem vital to present. The KPIs are exhibited according to the processes which need the most attention or if any decision needs to be taken. The detail of the KPIs presented vary between the meetings and are presented in different ways by different presenters. Hence, there is no standard format or template of reporting the KPIs.

Another important point obtained through observation was that, during the project meetings, the BQMs presented performance of processes which were important for the project, however, they were not important for PDQ to measure. There was a very thin line between what the project leader has to measure and what the business quality manager has to measure. From the interviews conducted further, a clear difference was visible regarding what PDQ upper management wanted to measure and the measures that BQMs thought they should measure.

5 Results and Analysis

In this chapter, insights gained from the combination of interviews, observation and immersion are synthesized with the knowledge gained from the literature study. The combination of knowledge has been utilized to generate suggestions for improved performance measurement and management. The chapter has been structured the same way as the literature review to provide an improved understanding to the reader along with context, starting with performance measurement and management, dashboard development and ending with the prototypes which is the end deliverable of the thesis.

5.1 Performance Measurement and Management

5.1.1 Results

The success of a product with the customer is directly dependent on two different aspects as the research study indicates: Perceived Usefulness and Perceived Ease of Use (Avlontis and Panagopoulos, 2005). In order to capture the essence of the two aspects of the final product, the customer needs to be involved in the product development process. These principles have been used whilst conducting this thesis. Hence, extensive interviews were conducted with the customers of the end result of this project – The Performance Dashboards. The interviews, along with observation and immersion provide the content for this chapter.

The purpose of the interview was to study how the potential users of the dashboard perceived performance measurement and management. The result of this series of interview uncovered surprising results that have been used throughout the thesis. All the interviewees were in agreement with the fact that there was no standard way in which the performance was measured. It was found that sometimes, the presenters of the KPIs went deep into levels that were deemed unnecessary for the attendees of the meeting.

Interviewee 1 (Attendee of the level 1 meetings) stated "*The performance measures are sometimes not calibrated to the level of the attendees of the meeting. I do not like to see drawings and in-depth technical pictures. The performance measures must be fact-based and holistic.*

Also, some items on the presentation just reported the status and did not need any decision to be taken by me. The KPIs must indicate the results of the process and not the details of how the process works."

What was interesting is when interviewee 5 was interviewed who was below interviewee 1 in the hierarchy and was one of the presenters of the KPIs at the meeting.

Interviewee 5 (Presenter at the level 1 meeting): "*I need to present all the statuses to the upper management to provide them a good holistic overview. It is necessary to show that the quality department is working adequately in the project. Apart from this, it is also necessary to present any risks in the projects and if any decision was required from the upper management.*"

The contrasting viewpoints of the two interviewees were obvious. The key takeaway from these two interviews is that the upper management was only interested in risks and if there will be any impact on the project in terms of time or cost. The upper management is not interested in the technical details of the project and also were not interested in processes that were actually performing well.

Interviewee 1 said "*I trust the team to deliver what they need to deliver and hence they do not need to present all the aspects of the project to me. They need to highlight only the risks of the project which need my attention.*"

However, the most important information was obtained during an interview with another upper management interviewee of PDQ. She revealed the objective and the strategy of the PDQ in CEVT:

"*The objective of the PDQ is to secure project quality and product quality in projects undertaken by CEVT in addition to making sure the product reaches the customers at the committed time, within the assigned budget and using the right techniques*".

This effectively provided the thesis with the success map for PDQ. This success map was deemed to be extremely important since the research project must strive to orient the end result of the project with the organizational strategy in order to deliver satisfactory results.

Another combination of interviews that is interesting to highlight is between that of two technical quality managers (Interviewee 9 and 10) who are presenters at level 2 and 3 meetings. While interviewing the TQMs, the conversation leaned more towards the process they were responsible for and hence, the contrasts in viewpoints revolve around this particular process. This process currently does not have an acceptable dashboard and the KPIs measured by both the interviewees with regards to the process differed. Through interviews, it was discovered that the KPIs are measured in different ways for the same process and that there were preferences in the way the same process was measured. Interviewee 10 was of the opinion that the numbers could be expressed in the form of a matrix which provides details of all the risks and shows the priority levels of the risks using colour coding. However, interviewee 10 measured different KPIs in the form of different numbers. Hence, there was an obvious difference in opinions regarding how the process should be measured.

The findings detailed above were observed inside the PDQ. However, more interesting findings were discovered when the interviewees outside PDQ were interviewed. Interviewee 14 was the leader of a certain process which was to be measured to check for performance of the project. When being interviewed, it was observed that the leader of the process measured the KPIs at a very detailed level that had contrast to the way PDQ measures the same process. PDQ only needed to check if certain activities were carried out at the time they are supposed to be done so and if the supporting documentation was in place. Interviewee 14, however, measured the numbers within each of these activities. These two different measures of the same process were perceived to be useful for the two departments in their own ways.

5.1.2 Analysis

Upon analysis of the data derived from interviews and the literature study, substantial knowledge was gained regarding the gap that existed between the current performance measurement and the ideal performance measurement. Sufficient evidence was acquired that proved a lack of alignment between the employees within the PDQ department and CEVT as a whole. Different perspectives were gained from different employees with regards to this topic. It was also observed that the strategic objectives of PDQ was not one of the factors that were considered while implementing the current performance measurement and management system.

In order to design a good performance measurement system, these aspects will have to be considered. Theory suggests that there are two categories of failure when it comes to performance measurement: Inappropriate design of the measurement systems and failure to implement it in a correct manner (Section 3.1.1). The following sections address these aspects and suggest the best way to establish an effective performance measurement and management system.

5.1.2.1 Design of the Measurement System

From the literature study, it was found that the key to designing an effective measurement system is to not directly jump into discovering what the organization should measure, but by looking into the organization's success map (Neely and Bourne, 2000). A success map is a cause and effect diagram that connects strategic objectives to business operations. Utilizing this principle, the research project sought to lay out the strategic objective in plain sight to make it easier to identify the right measures of performance.

The strategy of the PDQ department was found to be "*To secure project quality and product quality in projects undertaken by CEVT in addition to making sure the product reaches the customers at the committed time, within the assigned budget and using the right techniques*". Hence, the thesis has been conducted considering this and has strived to achieve an alignment between the strategic objectives and the end deliverable of the research project, the performance dashboards. In the later sections of the report, it can be observed that the dashboards only speak in the language of quality, time, technique and cost. However, the dashboards will fail if the strategic objectives are not cascaded down from the top management all the way down to the individual team members. Hence, one of the important suggestions of this research project is for the management to look into the strategic objectives and make sure they are cascaded down. This will help the employees understand the intentions behind the design of the dashboard.

While designing the dashboards, it has been made sure that the dashboards can be used by all three levels of the meetings that were identified in the thesis. This has been ensured by providing all the dashboards with drill-down capabilities such that the dashboard can be customized to address the KPIs in a way that the attendees of the meeting will find interesting to understand. In level 1 meeting, the holistic view of the entire project can be shown, and it is possible to even show the performance of the individual unit. Level 2 meetings will also find this interesting. Level 3 meetings, however, is more technical level meetings than business level meetings and is quite close to the project team members. Hence, the dashboards have the capabilities to drill down further into the individual PSS that make up a unit and the individual function groups that make up a PSS.

Another finding was that the KPIs that need to be measured were quite unclear and differed between the different levels of the meetings and between different organizations. This situation can be improved by upper management. The theory suggests that the management team has to be very explicit with the language they use when it comes to performance measurement (Section 3.1.1). It is suggested that the management clearly define what measures they would like to see from the presenters of the meetings so that they do not receive any unnecessary information that does not pertain to PDQ. This was done by constantly acquiring feedback from both the top management as well as the users of the dashboard with regards to what KPIs need to be measured and how it needs to be visualized.

5.1.2.2 Implementation

Theory suggests that failure to implement performance measurements happens mainly due to three reasons: Political, Infrastructural, and Focus (Section 3.1.1.2). Dashboards become a numbers game if not used appropriately. In general, leaders could use it to show why they are not producing the results and to push the blame elsewhere. CEVT management must assure the leaders that the purpose of the dashboard is not to reason with failure to perform but to use them proactively to perform better. This can be achieved by the upper management constantly communicating this during the meetings and encouraging an atmosphere of trust and mutual support.

With regards to infrastructure, in a lot of cases, the company has a lot of data required to be measured in some form or the other. They are found in multiple places with different people being in charge of it. The data is also stored in inconsistent formats in multiple databases that make the data difficult to gather in one place and analyze. CEVT also has a similar form of storage solutions that could pose to be a hindrance to acquiring effective dashboards. For example, documents of one of the processes are stored in a system called SharePoint but are viewed on a system called the Project Report Centre. However, the work of another process is performed and stored in a software called XFMEA and viewed in a system called the Synthesis Enterprise Portal which is external to the project report center. Also, some process documents are stored in SharePoint and viewed in the form of a tool in SharePoint and also on the PowerBI tool which is a data visualization tool. The thesis suggests that all the dashboards be viewed live on the Project Report Centre. The reason being that all the dashboards can be used at the same place which makes it easier to adapt and use the dashboards. Furthermore, CEVT has a BI development team that is competent to perform this action. The dashboards submitted by the research project is possible to be created for the project report center and no additional tools/skills are required to create the suggested dashboards.

With regards to focus, the theory suggests that measurement systems fail due to the amount of time and resources an organization needs to put in to establish the systems (Section 3.1.1.2). Individuals get frustrated with the implementation process. Also, sometimes the organization changes priorities and efforts are no longer put into implementing the measurement systems. The thesis suggests that a team devotes a large chunk of its time to implementing the dashboards. The dashboards must be created in collaboration with the potential users of the dashboard as well as the top management. Constant prototyping, testing, and feedback must be acquired from the top management as well as the potential users so that effective dashboards can be created that is both easy to use and useful to them. This also reduces the training required to get the team on board since the whole team was involved in the creation. This is in accordance with the technology acceptance model suggested by the theory (Section 3.4). In order to validate the thesis's conformance with the technology acceptance model, statements were derived from the users of the dashboard. Interviewee 2 said "*Yes, I believe that the dashboard prototypes presented are both easy to use and are very useful to the company. We will be implementing it soon with the support of the IT team*".

5.2 Dashboard Development

At CEVT, some KPIs and dashboards do presently exist. Some of them are used more as compared to the others. They are also available in different systems and acquire data from multiple sources present in different systems within the organization. To understand the intricacies of the current state of dashboard management, observation and immersion have been carried out as part of the research methods. These methods have proved to be the best since the study was required to be carried out wearing the lenses of the potential users of the dashboard.

5.2.1 Dashboard Development Framework

The creation of dashboards has been executed using the dashboard development framework proposed by Pauwels et al. (2009) as the skeletal framework. The thesis uses the theoretical backing of the framework and implements it in the dashboards to be used for the different quality processes. This allows for all the factors that need to be considered when dashboards are created and result in a dashboard that is both useful and easy to use.

The adoption and success of the dashboards is driven by five main factors: Demand, Supply (Metrics availability), the fit between demand and supply, implementation process and predisposition of users.

Demand (Box 1):

The most important factors of demand as shown in box 1 of the framework are:

- *Users:* Although the dashboards were created primarily for the use of the PDQ department, the dashboards can effectively be used by the R&D department also. In fact, the thesis recommends that the entire organization use the same dashboard in order to enable everyone to "speak the same language". The users of the dashboard, as found are both the upper management and the project teams. These potential users attend three different levels of meetings in which different details of the information is viewed with a different "lens". Level 3 meetings view the dashboard with a "technical lens" and level 2 and level 1 meetings view the dashboard with a "business lens".

- *Organizational Decision Style:* This factor relates to the way of working and decision-making style at CEVT. It is observed that CEVT uses two different styles of decision making: data-driven as well as experience-driven decision making. Hence, the dashboards that are created must support both these styles. However, the dashboards that have been created mostly encourage data-driven decision-making process. Experience-driven decision-making process is only required when forecasting needs to be done in the project and in a lot of cases this judgement or "gut feeling" could be wrong. To account for this, the dashboards have investigated the process of proactive forecasting which does not require the decision maker to make decisions for the future based on the gut feeling.

- *Interdepartmental Relations:* The dashboards have been created to encourage good interdepartmental collaborations and align the way all the departments view the processes. The research project hypothesizes that the departmental relations will only improve with the usage of a common dashboard.

- *Industry:* CEVT being in the fast-paced automotive industry has their own processes in their project development. Hence, they need to use a dashboard approach tailored to their use and cannot use generic dashboards.

Supply (Box2):

The factors driving the supply side of the dashboard as shown in box 2 of the framework are:

- *Metrics:* The data available for the dashboards are all available in different systems. However, some of the data was found to be incompletely filled, thereby hindering an effective dashboard. Suggestions for improving data availability for all the processes have been detailed in the dashboards chapter (Section 5.3).

- *Sophistication:* CEVT requires two types of visualization: as-is conditions and what-next conditions. As-is condition is to show the current status of the project. What-next is to show the forecast status of the process. The possibilities of including both conditions have been explored while creating the dashboards.

- *Visual Display:* Visual display has been designed to provide all the data with simple visualization techniques like stacked bar charts, line charts, and pie charts. Visual indicators to show the as-is condition versus the target condition is also used. Colour coding like red, green and yellow has been used to immediately provide a judgement of the status. Additionally, shapes have also been used to account for the colour-blind users of the dashboards.

- *Drill-down Capabilities:* As previously stated, all the dashboards have been provided with drill-down capabilities to customize the same dashboard to the level of the attendees of the meeting. A good dashboard is one which is understood by all levels of the organization.

Fit between Demand and Supply (Box 3):

The fit between demand and supply has been ensured in the following ways. The information presented on the dashboard is designed to be relevant and useful to all the potential users of the dashboards. The dashboards have been created with continuous feedback from the potential users to ensure this fit. The information presented is also aligned with the strategic objectives of the company and will provide a performance measurement system which considers project performance with respect time, technique, quality, and cost. The processes usually do not have a lot of strategic options that change the course of a project, hence there was no need for a what-if data analysis. Only as-is and what-next statuses have been visualized. The company works on a mix of data-driven and experience-driven decision making. The dashboard caters to a data-driven decision-making approach. The visual display has been customized to show data in a way everyone understands. In this way, the fit is ensured.

Implementation (Box 4):

As previously stated, a performance measure will fail if the implementation is a failure. Top management support and user involvement is key when it comes to implementation. The thesis was initiated by the top management and hence the project has adequate management support. All the dashboards have had the users involved during the development and testing phase. Requirements were obtained from them and the dashboards were created iteratively with continuous feedback from them. Prototyping of the dashboards has also been carried out by implementing the dashboards on a live project. Since the dashboards created have been done so with the current infrastructure in mind, the implementation is possible since all the proposed dashboards can be created with the current IT systems and the competence of the IT teams. In order to implement the dashboards, it is suggested that the top management allocate sufficient time and budget in order to implement them since they are the biggest risks while implementing such projects. It is also suggested for the management to take an active part in the development and feedback cycles in order to ensure a usable and useful product delivered on time.

Predisposition of the Users (Box 5):

A dashboard with a good fit between demand and supply must elicit a positive response from its users with the following key elements:

- *Attitude:* Two main drivers that elicit a positive response from its users are its perceived usefulness and the ease of use. This is the Technology Acceptance Model (Avlontis and Panagopoulos, 2005). This has been ensured by continuously involving the potential users of the dashboards and continuous feedback.

- *Trust:* Decision makers need to ensure that the dashboard is trustworthy and that the system cannot be cheated. Sufficient systems must be in place to drill down to investigate strange patterns. With the development of the dashboards, gaps in the processes and gaps in the available data have been identified and the potential users have been notified of the gaps. Ways to fill the gaps identified have also been documented in the following sections of the report under the individual dashboard sections (Section 5.3). Drill-down capabilities have been provided to immediately investigate strange patterns shown on the dashboard.

- *Expectations Management:* A dashboard will not be without initial bugs and problems. Expectations have been managed well since the potential users were involved in the development.

The Adoption and Success of Dashboard (Box 6):

This box is dependent on the fulfillment of the other five boxes. The adoption and success of a dashboard can be measured on four dimensions:

- *Adoption and Use:* It is suggested that the dashboard be used by multiple departments and a congruence be obtained. The dashboards will not only help PDQ monitor the quality process but also help the R&D monitor and proactively perform the processes. The dashboard has gone through multiple iterations using testers so that it is accepted, and the expectations are managed. It has been ensured that the dashboard fits the purpose they would like to use it for by continuously involving the users and the top management and following a continuous cycle of prototyping and feedback until the users were happy with the dashboard. Interviewee 5 mentioned that he liked the dashboards and said these dashboards will be very useful for them.

- *Increased Accountability:* The dashboards have been designed to ensure traceability to the owners of the processes. The drill-down capabilities can point an issue to the correct issue owners. The names of the responsible persons have also been suggested in the proposed dashboards to improve accountability.

- *Improved Effectiveness and Efficiency*: It is suggested that the different departments utilize the dashboards to better monitor and better deploy their efforts to obtain an increase in effectiveness and efficiency.

- *Learning*: Dashboards are not just made for decision making. They are also designed to enhance learning and cross-functional knowledge transfer. It must encourage implicit learning within individuals who use the dashboard. This has been attempted while creating the dashboards. A disciplined usage of the dashboards will help the users learn more about the processes and deploy improvement actions to improve the processes.

5.2.2 Dashboard Development Stages

The development of dashboards has been undertaken following the five dashboard stages delineated by Pauwels et.al (2009). However, with the progress of the thesis, while researching the use of performance measures, certain gaps in the processes were discovered. Attempts have been made to plug these gaps and these process improvements have been addressed in this report. Also, for some of the dashboard proposals to work successfully as designed, there will have to be some changes in the way-of-working of the processes. In some cases, the way the employees handle the data and utilize the database has to be changed. These have also been addressed in the report. These proposed process improvements have been added as a separate stage called Stage *VI: Process Improvement Proposals.*

Stage I: Selecting the Key Metrics

Amber (2003) talks about two approaches for metric selection: General Approach and Tailored Approach. After learning the working of all the different processes using observation and immersion, it was found that the tailored approach was the way to go about it. This was due to the fact that different processes viewed different metrics in different ways. All the processes had their own strategy to track its performance towards their specific objectives. In order to select the metrics, as suggested, high-level communication was established between: a) People who will use the system (All interviewees) b) People who will be measured by the system (Interviewees 3-16) and c) People who will use the dashboard to make decisions (Interview 1 and 2). This enabled a cross-functional collaboration in the selection of the metrics and the eventual development of the dashboard. The functions involved were from different levels of the hierarchy within the PDQ as well as outside the department.

Stage II: Populating the Dashboard with Data

While developing this stage, care was taken to populate the dashboard only with the data that will be useful to the potential users of the data through interviews, prototyping, and feedback. All the efforts have been taken to bring these KPIs as close as possible to the external factors such as the impact on customers, both internal and external and impact on time, technique, quality, and cost. This is believed to provide more actionable insights when viewed by the potential users. The dashboards do not just provide the as-is condition of the processes, but also what-next conditions. Wherever possible, it has also been ensured that recommendations are provided for the decisions to be made rather than just providing the present condition to the management and waiting for them to provide guidance/decisions. This enables proactivity in the usage of the dashboard. In some cases, the metrics that were currently being viewed for certain processes have been found inadequate and proposals have been made to view better metrics. For example, in the design review process, the metrics that were followed were if the design review excel sheets were uploaded and approved on time. However, what was really important to measure was the status of the deliverables mentioned inside the design reviews. Bringing out these metrics provided more actionable insights and efforts could be proactively taken to ensure quality.

Some of the dashboards have proposals that could not be worked with the presently available metrics. However, if the proposed metrics are established, they could be extremely beneficial in the long term.

Stage III: Establishing Relationships between the Dashboard Items

Simply putting on the available metrics on the dashboard cannot always address the cause-and-effect relationships between the data that could improve the performance of the business. Hence, effort has been taken to determine the underlying relationships between the different dashboard items. This has been done by making the team do a relationship study and brainstorm the relationships that exist between the different processes. The results of the study have been provided in section 5.3. For example, in the function follow up dashboard, a chart has been proposed which indicates which of the functions will not be mature enough for the vehicle testing process which happens much later in the project. In this way, opportunities to uncover relationships between two dashboard items have been investigated.

Stage IV: Forecasting and Scenarios

This stage involved discovering the what-if analysis as a way for managers to evaluate all the options available and take well-informed decisions. However, in the case of CEVT, there was no possibility of providing options and forecasts that would drastically change the direction of the project. What was more useful to have as a dashboard item was a what-next analysis. The upper management said that it was very useful to know what the current state of the project is and to see if they will reach the target at the time they predicted. If they discover that they might not achieve the target in the future, they could put more resources immediately to ensure that they hit the target in the future.

Stage V: Connecting to Financial Consequences

The framework includes a step of connecting the dashboards to financial consequences, but this has not been carried out since at this point the metrics cannot point to a direct financial consequence. The calculations do not exist and cannot be established at this point. However, the stage also speaks in terms of connecting the KPIs to value created for the stakeholder and helping align the corporate goals, the investor and the end customer. This has been carefully considered during development by considering connections to other processes and process owners down the line in the project. An example of such a connection has already been given with respect to the connection between functional follow up dashboard and testing team. A significant amount of money and time can be saved if the functional follow up dashboard tells the testing team which of the functions cannot be expected to work. Hence, time and resources will not be spent on testing that function. Hence, in this way, an indirect financial consequence can be derived.

Stage VI: Process Improvement Proposals

As discussed previously, while researching the use of performance measures, certain gaps in the processes where uncovered which could lead to incorrect performance measurement. Certain details that needed to be brought to the attention of the management were currently not brought out (For example, expected completion date in design reviews). Hence, the dashboards have addressed such information.

Also, the dashboards that have been proposed do not just utilize the available data. They put some demands for data that needs to be extracted from the system and modified in a way that can be utilized to view on the dashboard to provide useful performance measures. These potential process improvements have been detailed under section 5.3 for the individual processes.

5.3 Dashboard Prototypes

In the thesis, six different dashboard prototypes have been created, one for each process that has been investigated. All the six processes have a different story and need to be measured in different ways and hence have been treated as six different cases in the following sections. Also, while creating the dashboards, a number of gaps in the processes were encountered which have been highlighted in the following sections.

The principles of effective dashboard creation, as well as data visualization, have been used in the creation of the dashboards. Pauwels et al. (2009) distinguish between two types of dashboard features: functional features and visual features (Section 3.2). Functional features describe what the dashboard can do. These functional features have been derived using the dashboard development framework and have considered all the factors proposed by the framework thus ensuring its effectiveness and checking the “Perceived Usefulness” box according to the technology acceptance model. Visual features refer to how effectively information is collected and visualized for the decision maker. The visual features have been derived using the nine practices highlighted by Tufte (2001) with regards to graphical excellence (Section 3.3). The dashboards are suggested to be implemented on the PowerBI tool which is a business intelligence tool used for performance measurement and visualization. The company already has a license for this tool. In this way, the feasibility of implementation has been ensured throughout the development stages.

5.3.1 Case 1: Failure Mode and Effect Analysis

5.3.1.1 Process Description

Failure Mode and Effects Analysis (FMEA) is one of the essential tools for improving product and process design. An FMEA intends to assess what features or failure modes could affect the product quality as perceived by the customer and how these risks can be reduced. The FMEA could be developed to deal with a component, a sub-system or for a complete system. At CEVT, the process is used as the standards indicate but with their own classification of risks. The risks obtained in their FMEAs are either classified as critical classified risks or CC risks and Significant Classified Risks or SC Risks. If the risks do not fit this criterion then they are unclassified risks. CEVT essentially aims to reduce the classified risks before reducing the unclassified risks.

CEVT also works with the FMEA process in four different phases: Planning phase, initiation phase, execution phase, and follow-up phase. At the planning phase, the process of robustness assessment is carried out to determine if an FMEA needs to be performed. At the initiation phase, the R&D engineers must have initiated the process of identifying the different failure modes associated with their functions and their corresponding causes, action controls, and effects. The risks must also be classified as SC or CC if they match the criteria. At the execution phase, the engineers start to brainstorm about the actions that can be taken to reduce the risk. They fill in the recommended actions, actions taken and again classify their risks based on the criteria. At the end of this phase, the reclassification of all the risks must have been documented. To document the FMEAs, CEVT uses a tool called XFMEA which provides the template to fill the contents of the FMEAs and provides a structured storage method. This template contains numerous fields such as unit name, PSS name, failure mode, causes, design controls, effects, risk classification, recommended actions, actions taken, etc. At the follow-up phase, the completed FMEAs are assessed and documentation is verified.

5.3.1.2 KPI Analysis and Visualization

After assessing the current state of the FMEA dashboard, the author held unstructured interviews with the stakeholders of the dashboard in order to understand the requirements. The interviews were held with stakeholders in the different levels of the reporting structure to understand what level of detail needs to be viewed at the different levels. From the interviews, it was discovered that there are different KPIs associated with the different stages of FMEA. An FMEA is carried out throughout the product development phase. The columns on the template get filled gradually over the entire phase as the engineers uncover more information. Hence the dashboard will not have all the necessary KPIs displayed at once. At present, CEVT uses a dashboard that is provided along with the XFMEA software. The number of functions, failure modes, effects, causes, controls, and actions are the numbers that the PDQ department currently views on the dashboard as shown in figure 5.1. It also shows the percentage of these elements that have been analysed. However, there is no documentation of the target number of FMEAs that are supposed to be performed. Hence, there is no visualization of data that can provide the users of the dashboard with an easy grasp of the progress with respect to the completion of FMEAs as compared to the target number of FMEAs. There is, however, a bar chart showing the issues ranked by initial risk priority number, a KPI that is not used by the PDQ. The dashboard also does not display the number of classified risks, their respective recommended actions and if actions have been taken or not which is the most important for PDQ to monitor during the execution and follow-up phases.

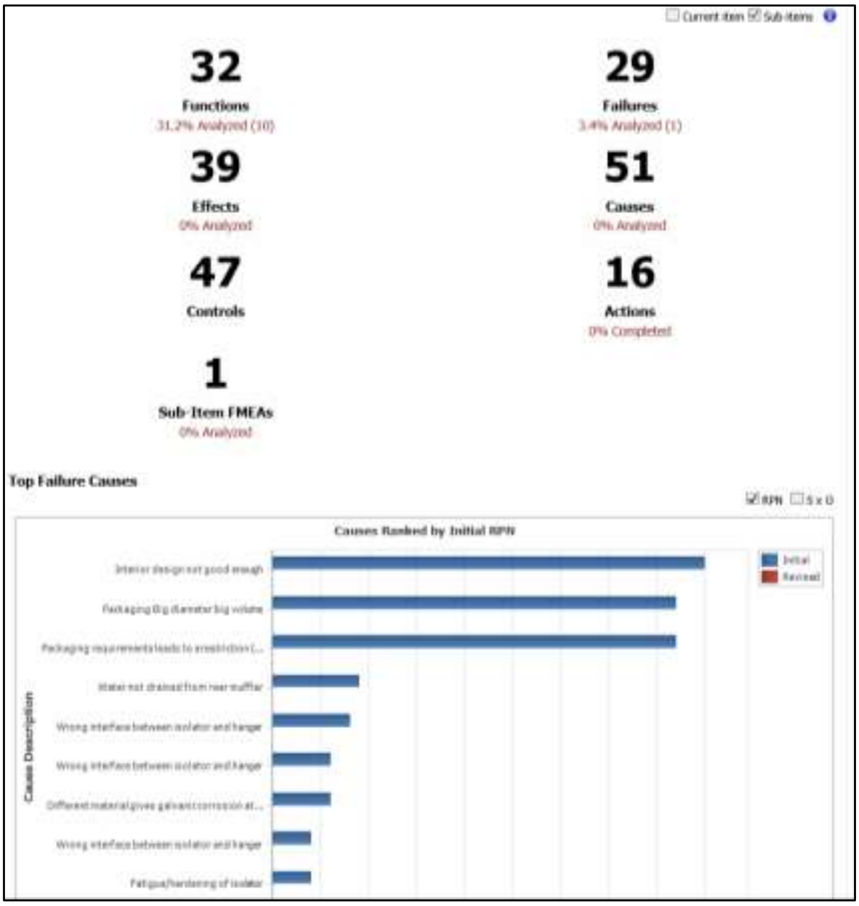


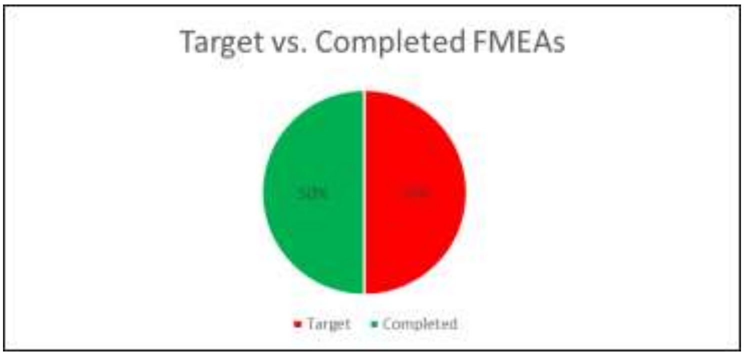
Figure 5.1: FMEA Dashboard

5.3.1.3 Dashboard Prototype

As gathered from the findings, the FMEA process is split into the planning, initiation, execution and follow-up phase and monitor different KPIs to check progress. It was found out that the following items were the KPIs for the different timelines of the FMEA process.

FMEA Planning:

This is the first stage of the FMEA process in which the different R&D teams decide if FMEAs are supposed to be done for their parts and what type of FMEAs are supposed to be done. This is decided in a process called robustness assessment. However, the process gap observed is that the number of FMEAs to be done are not counted and documented. Hence, a piece of important information is not captured, the target number. Only if the target is known can the present progress be measured. Hence, one of the process improvements proposed is a way to count the target FMEAs in the robustness assessment. Given in figure 5.2 is a part of the dashboard showing the target versus completed FMEAs.



Unit-wise Target vs. Completed FMEAs

Units	Target FMEAs	Completed	% Completed
Chassis & Safety Electronics	600	490	81,67
Electrical	500	116	23,20
Lower Body Structure	200	188	94,00
Powertrain Integration	1500	1094	72,93
Total	2800	1400	50,00

Figure 5.2: Target vs. Completed FMEA

FMEA Initiation:

Here, the KPIs need to show the number of FMEAs that have been initiated. The PDQ need to closely monitor that the number of potential failure modes are growing. This growth must also be noticed at the different unit levels and the PSS levels to see if they are working according to the plan to complete the target number of FMEAs. Hence, for the initiation phase, the KPIs which have been deemed important to be shown are:

- Number of Potential Failure Modes
- Number of Causes
- Number of Potential Effects of Failure
- Number of Initial Classified Risks
- Number of Recommended Actions
- Number of Actions Taken
- Number of Revised Classified Risks

The data visualization method that was chosen was a pivot clustered column chart which provides the function to show the numbers in a way such that it can be shown the for the whole project and also be drilled down to the individual unit and PSS level. At different stages of the project, the different columns of the FMEA worksheet need to be filled. The column chart will be indicative of the columns being filled at the different stages. It is also useful when the stakeholders want to compare the numbers against each other. For example, the number of recommended actions must be equal to the number of classified risks. The bar chart will immediately indicate to the viewer if the engineers have not identified the recommended actions to handle the risks. This will make it easier for the PDQ department to push the engineers to identify the recommended actions. The column chart also includes the data table which shows the numbers indicated in the bar charts. The figures 5.3 and 5.4 are parts of the dashboard designed to show the progress of the entire project as well as individual units, PSS and function groups.

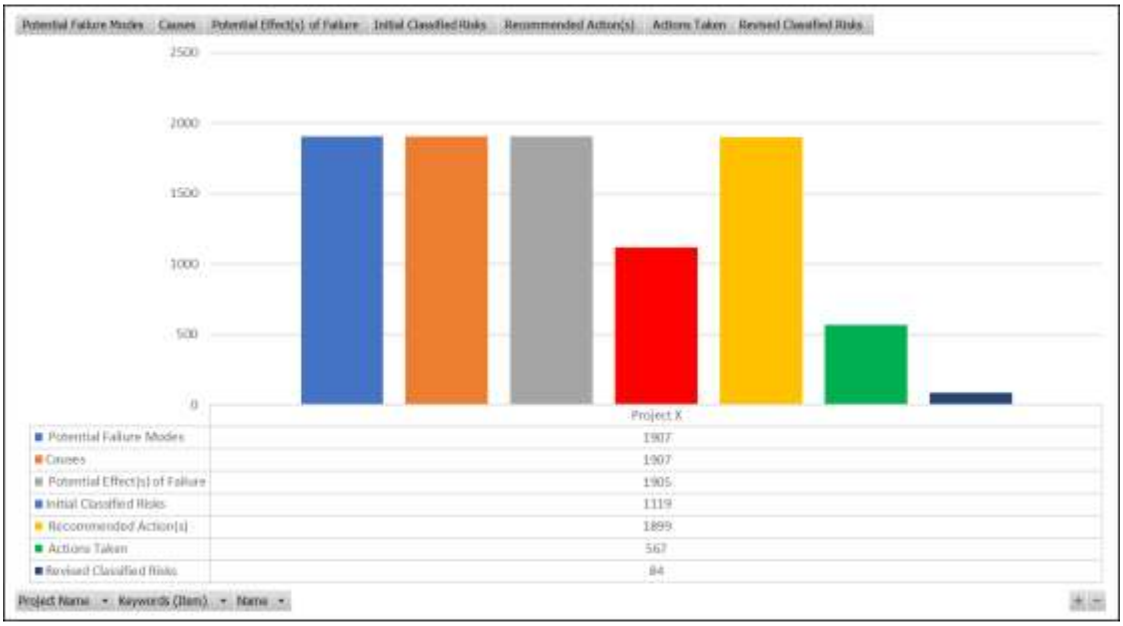


Figure 5.3: Overall Project Progress

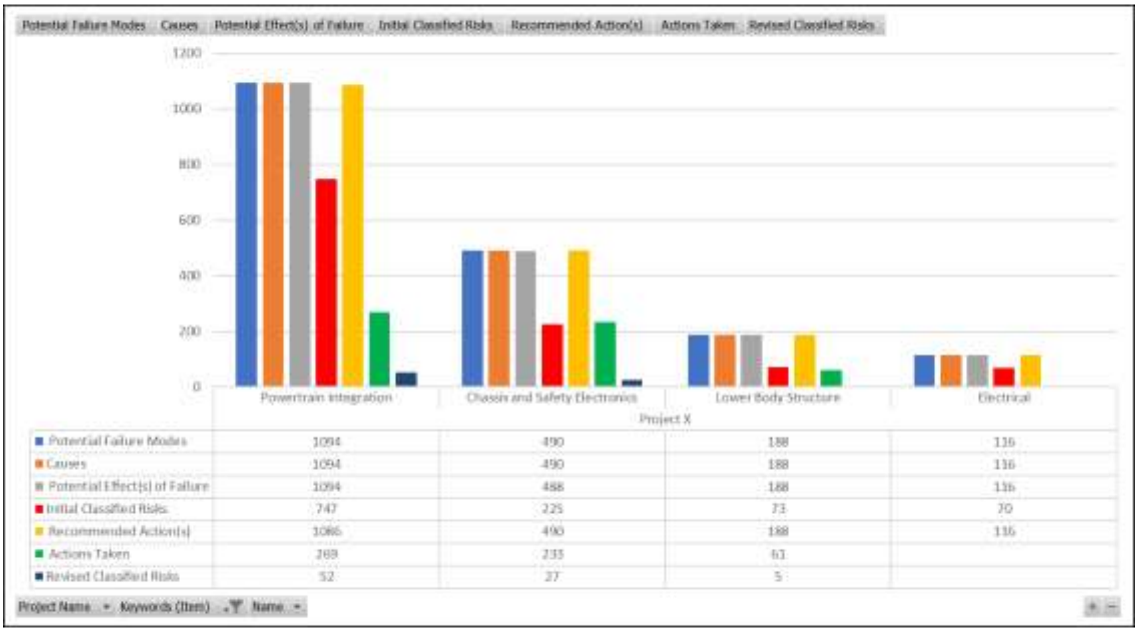


Figure 5.4: Drill-down to Unit Level

FMEA Execution and Follow-up:

This is the phase where the PDQ team checks for KPIs that indicate whether or not the recommended actions proposed in the initiation phase have been executed to handle the risks and what the revised classification of these risks are. The data visualization method that was chosen was a combination of a pivot clustered column chart and a table which shows all the risks. The content of the charts that were important at these phases was found to be:

- Number of initial significant/critical risks
- Number of Recommended Actions
- Number of Actions Taken
- Number of Revised significant/critical risks

The risks have been shown by splitting the risks into critical and significant risks since these are the risks that must be in focus during these phases and the actions taken need to handle these risks in particular. Hence two pivot column charts are used to visualize the critical and significant risks respectively. Apart from the charts, tables have been used to show the individual FMEAs and their content. These FMEAs are also shown at the project, unit and PSS level. They are auto-filtered based on which part of the chart is clicked. If unit A is clicked on the chart, then only the FMEAs pertaining to unit A appear below the chart.

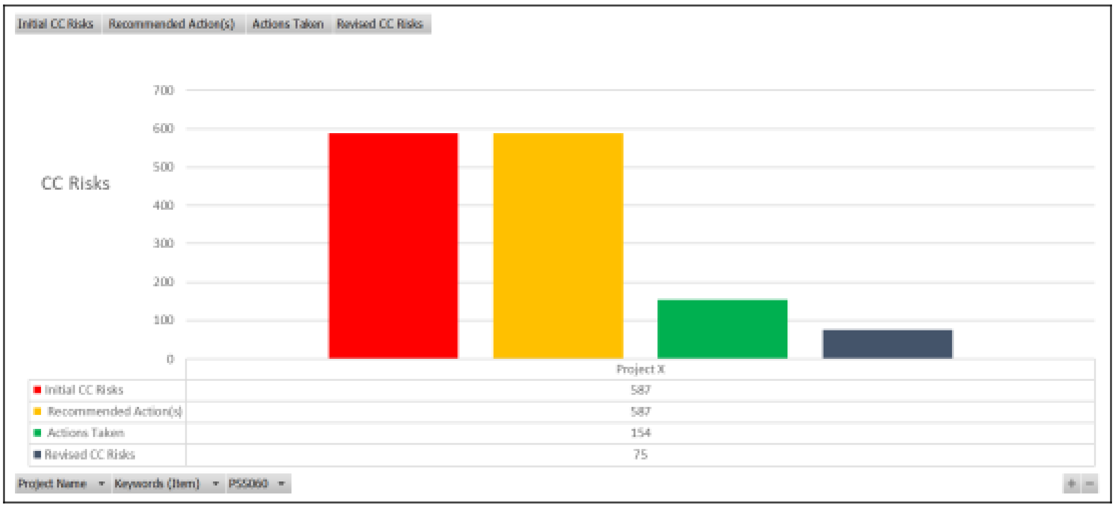


Figure 5.5: Overall CC Risk Status

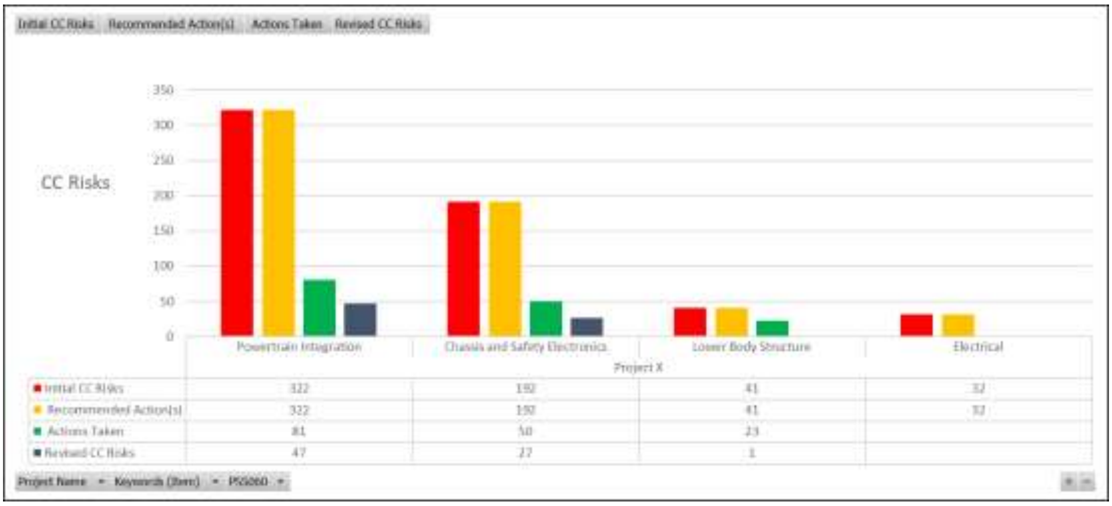


Figure 5.6: Unit-wise CC Risk Status

The dashboard created is a customizable dashboard suited to be used at all three levels of the meeting structure. To the upper management attending the level 1 and level 2 meetings, the overall project status, as well as unit-wise project status, can be shown. In the level 3 meeting within PDQ and with the R&D teams, a more drilled down dashboard showing the performance of the individual units, PSS and function groups can be shown. It also allows the different leaders to compare the performance of their team to that of the other teams. In this way, the dashboard is designed to be used by all the potential users of the dashboards both within the PDQ and the R&D teams. This aspect was validated by interviewee 2 who is a part of the top management and also the rest of the interviewees. For example, interviewee 7 said he thought the drill-down capabilities provides them a lot of information in a convenient manner.

Another proposal was made to provide a more proactive way of monitoring the actions taken. This will require a few process changes. While performing the FMEA, when the engineers decide the recommended actions, they must also fill in the planned completion date of the action. This allows them to commit to a target date and also allows the PDQ department to follow the weekly progress of the different actions. Since all the actions will have a planned completion date that is set into the future, the PDQ can proactively know how many actions they are supposed to follow up on in the coming week. The dashboard can pick up this data to show a current versus forecast of actions completed as shown in figure 5.7.

Figure 5.7: Current vs Expected Actions Taken

5.3.2 Case 2: Design Reviews

5.3.2.1 Process Description

A design review is a standardized and structured way to track the status of all components included in a design task. All the components/parts that are used in a project needs to have design reviews done on them. In layman terms, it can be defined as the checklist that the engineers must follow while developing a component for the car. It points out the most important deliverables/requirements that the component must fulfill and highlights the timeline for all the deliverables. Hence, if the design review checklist is followed correctly with respect to time, the component will be ready to be manufactured when the manufacturing phase begins. There are five design reviews that must be performed throughout the development to ensure that the component is at the right level of maturity at the right time. The design review must be approved by the module team director when the review is finished. When the design review is approved, it is deemed that the component is valid to be moved to the succeeding phase.

At CEVT, design reviews are done on macro-enabled excel sheets. A single design review can have a single component or multiple components being tracked on the same sheet. The decision is left to the R&D engineer to make. These excel sheets are stored on the design review document portal for it to be tracked. They are mapped to the appropriate function group, PSS and the unit to which it belongs. It also has the indication to show the status of the design review. It can be shown as ‘Approved’, ‘Draft’, ‘Pending’ or ‘Rejected’. The responsibility of the PDQ (for now) is to make sure these documents are uploaded, reviewed and approved on time.

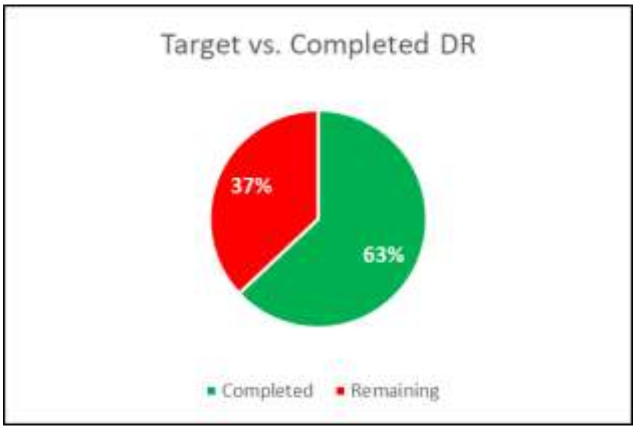
5.3.2.2 KPI Analysis and Visualization

At present, the dashboard shows the number of documents that have been uploaded and which phase they are at (Design Review 1, 2, 3, 4 or 5). Although they are mapped to their respective function group, PSS and unit, they are not always tagged with respect to a part number since it is not mandatory to fill in the part number while uploading the excel sheets. Hence, it is difficult to track a design review for a particular part on the document portal. The dashboard only keeps track of the design reviews that have been uploaded. It does not indicate if an R&D engineer has failed to upload a design review which is quite serious. In essence, what is missing is an indication of how many design reviews are supposed to be uploaded. Only if the target is known, the current situation can be judged to be on track or performing badly. The dashboard also does not indicate if the submission of a design review is delayed. A design review could be in draft status for longer than the deadline and the dashboard would not show it since the expected completion date is not documented by the document portal. Hence, the entire capability of the present dashboard is just to count the documents uploaded on the document portal.

Apart from tracking the documents, the dashboard is also not equipped to show if the deliverables listed in the design review have been finished on time. A design review can have a lot of important deliverables unfinished but PDQ has no way to identify this. The consequence of this is possibly a delay in the completion of the part which may lead to significant financial losses. Hence, the actual KPIs to be measured is not just the uploading and approval of the documents, but also the timely completion of the deliverables listed inside the design review and this is an area that is presently not possible to measure and visualize.

5.3.2.3 Dashboard Prototype

The content of this section has two types of information: A dashboard for the current state of performance measurement and proposals of what metrics should actually be monitored that are not being done so at this point. Currently, PDQ only monitors if the design reviews are uploaded and approved on time and which phase they are at (Design Review 1, 2, 3, 4 and 5). It is not possible to find out if an engineer has failed to upload a design review. The dashboard can only track the ones that have been uploaded. Hence, there is no target number of design reviews against which CEVT can measure its current status. Therefore, the first proposal for the dashboard is to make the engineers upload all the design reviews in a draft mode when they start the process. When they upload the design reviews, it must be made mandatory for them to tag the correct parts. If these two actions are done, PDQ can know the target number of design reviews and monitor their progress. Figure 5.8 below provides this information.



Units	Target	Remaining
Chassis & Safety Electronics	500	200
Body & Exterior	400	100
Electrical	300	100
Infotaintment & Driver Information	200	100
Interior	200	100
Powertrain Integration	300	100
Powertrain Engineering	500	188
Total	**2400**	**888**

Figure 5.8: Target versus Remaining Design Reviews

The table above provides the users with the number of design reviews remaining. However, it is also important to know what the status of all the design reviews are. They could be "Approved", "Draft", "Pending" and "Rejected". Figure 5.9 gives an indication of the status of all the design reviews of all the units in one chart. The chart also has drill-down capabilities to see the status of individual PSS and function groups. The status of design review phased (1, 2, 3, 4 and 5) can be viewed individually as well as all of them combined.

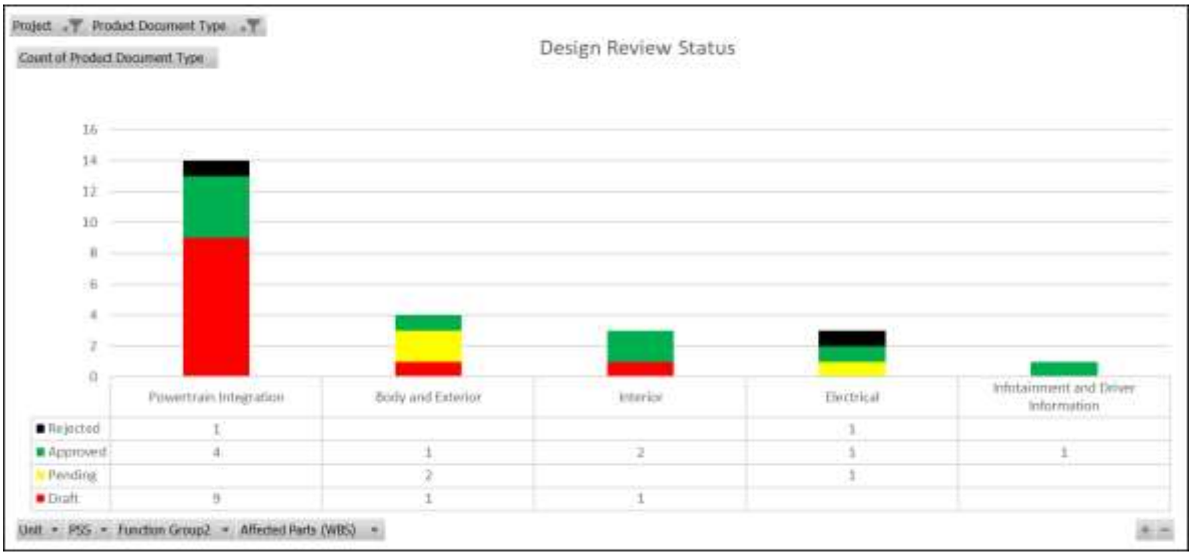


Figure 5.9: Design Review Status

The above chart combined with figure 5.8 provides an overall view of the current status of design reviews. What is missing from the above charts of the dashboard, however, is the information regarding whether or not the statuses are on target with regards to time. A proactive way to monitor the status would be to capture the planned completion date for all the design reviews uploaded and checking its statuses weekly. The chart below gives the information of the total number of design reviews that is supposed to be done for the project (1000) and it shows the number of approved, pending, draft and rejected design reviews. However, more importantly, the chart also shows how many design reviews are supposed to be completed on a weekly basis. For example, in week 30, 177 design reviews have been approved, however, according to what the engineers predicted 220 design reviews should have been approved. The following week, there are supposed to be 240 approved design reviews. Hence, the actionable insight that it provides the viewer is that the target is not being met this week and the target for the following weeks are known, hence they will have to speed up the process if they want to keep up with the curve. At the end of the project, the entire column must be green. The chart provides a good visual indicator that is simple to understand upon glancing.

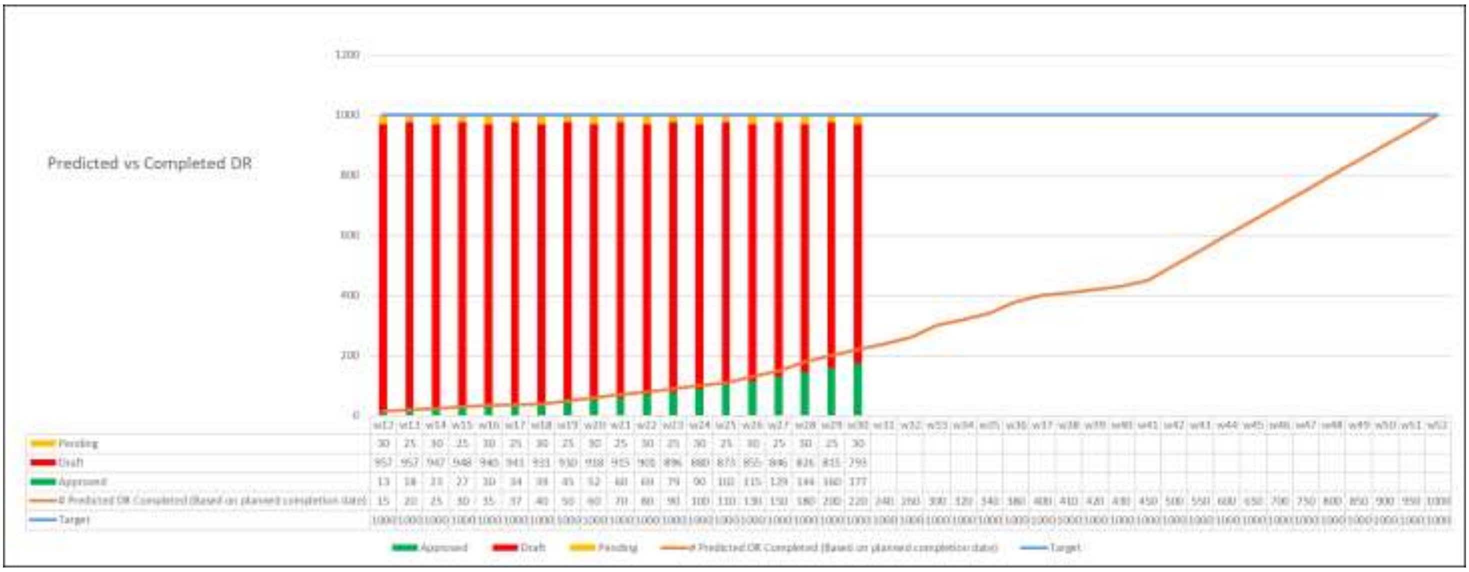


Figure 5.10: Weekly Progress Tracker

The dashboard presented above is a good tracker of the status with regards to the current way of working. However, further research uncovered the importance of monitoring the deliverables that is listed inside a design review for every part. It was discovered that some of the deliverables inside the design review sheet were in fact some of the processes that are being tracked externally using their own dashboards. For example, one of the deliverables of a design review is whether or not FMEA is at the adequate status that it is supposed to be at this point. If this is listed as a “No”, there is no way PDQ can know it since it is a line inside an excel sheet. In this way, quite a few deliverables can be unfinished long after they were supposed to be finished and the information cannot be automatically highlighted to the decision maker.

The proposal of the research project is to move away from using excel and digitalize this process. The system can be made aware of the timelines of each deliverable in a design review and can highlight the ones which are not complete or not going to be complete at the planned time. Such information from all the parts will allow the dashboard to provide a good performance measure for the entire car including all its parts.

5.3.3 Case 3: Program Quality Sufficiency Planning

5.3.3.1 Process Description

Program Quality Sufficiency Planning is a preventive quality process that is used to prevent failures that have happened in the past, to happen in the current and future projects. It is implemented in the product development phase of the car. Real life quality issues that have occurred in cars used by the customers are captured and are fed into the PQSP process as input. The PQSP process then distributes these issues to the owners of the issues within the R&D. The engineers then have to come up with a plan (known as sufficiency plan) to ensure that the same problems do not occur in the current project. The process is owned by the PDQ department, however, the process is executed by the R&D department. The responsibility of the PDQ is to ensure all the issues have a sufficiency plan to avoid the issues in the current project. PDQ also keeps track of the timeline and tries to get all the sufficiency plans in place before the development phase ends.

5.3.3.2 KPI analysis and Visualization

The PQSP process performance is measured using a KPI known as IPTV scores (Issues per Thousand Vehicles). Each issue encountered by PQSP is given a score called the IPTV score based on its occurrence and severity. All such issues and their IPTV scores are summed up to provide a total IPTV score. The work of R&D is to come up with sufficiency plans and reduce the IPTV score. In the ideal scenario, at the end of the product development phase, all the issues must have plans and hence the IPTV score will have reached zero.

The way the KPIs are visualized is using a graph which shows a glide path with time (Milestones) on the X-axis versus the IPTV scores on the Y-axis (See figure 5.11).

Figure 5.11: PQSP Target vs Actual Glidepath

As can be seen from the graph, the red line is called the actual glide path and the green line is the target glide path. The numbers on the green line indicate the target IPTV scores that must be achieved at the different milestones. At the end of the product development phase, both the glide paths must coincide as indicated by the graph. Presently, there are no visual dashboards that show the progress other than the glide path. Numbers are used to indicate the IPTV scores for the entire project as well as for the different units that are part of the project. These numbers show the current IPTV score versus the target IPTV score at the next gate. The figure shows that the IPTV score must have been reduced by 85% at the TPS gate, 95% at the TPC gate and 100% at the FDJ gate. These are the only target figures provided throughout the project. The gates against which the IPTV scores are measured are significantly spaced in the timeline of the project. Hence, the numbers shown as the current IPTV score does not provide a good indication of whether or not the target IPTV score will be achieved at a gate which is possibly 15 or even 50 weeks away.

5.3.3.3 Dashboard Prototype

In the case of the PQSP process, the thesis suggests that the tool itself can be modified to be used as the dashboard. This was considered possible while investigating the PQSP tool and it was found that the tool could be provided with more capabilities that could make it act as a dashboard apart from just being a tool which shows all the issues and IPTV scores. After interviewing the three levels of the hierarchy, it was discovered that level 1 meeting did not really care for the IPTV scores and the individual issues. This was confirmed by interviewee 1 who said: "*The KPIs must indicate the results of the process and not the details of how the process works*". They only required to know if the PQSP process was on track and if they will hit the target at the achieved time. Hence, the suggestion for the dashboard at this level of meeting was just a dashboard which showed all the projects that CEVT is undertaking and the progress of each of the project. A program status indicator has also been added in the page which visually indicates if the project is on track. A screenshot of the first page of the tool is as shown in figure 5.12 below.

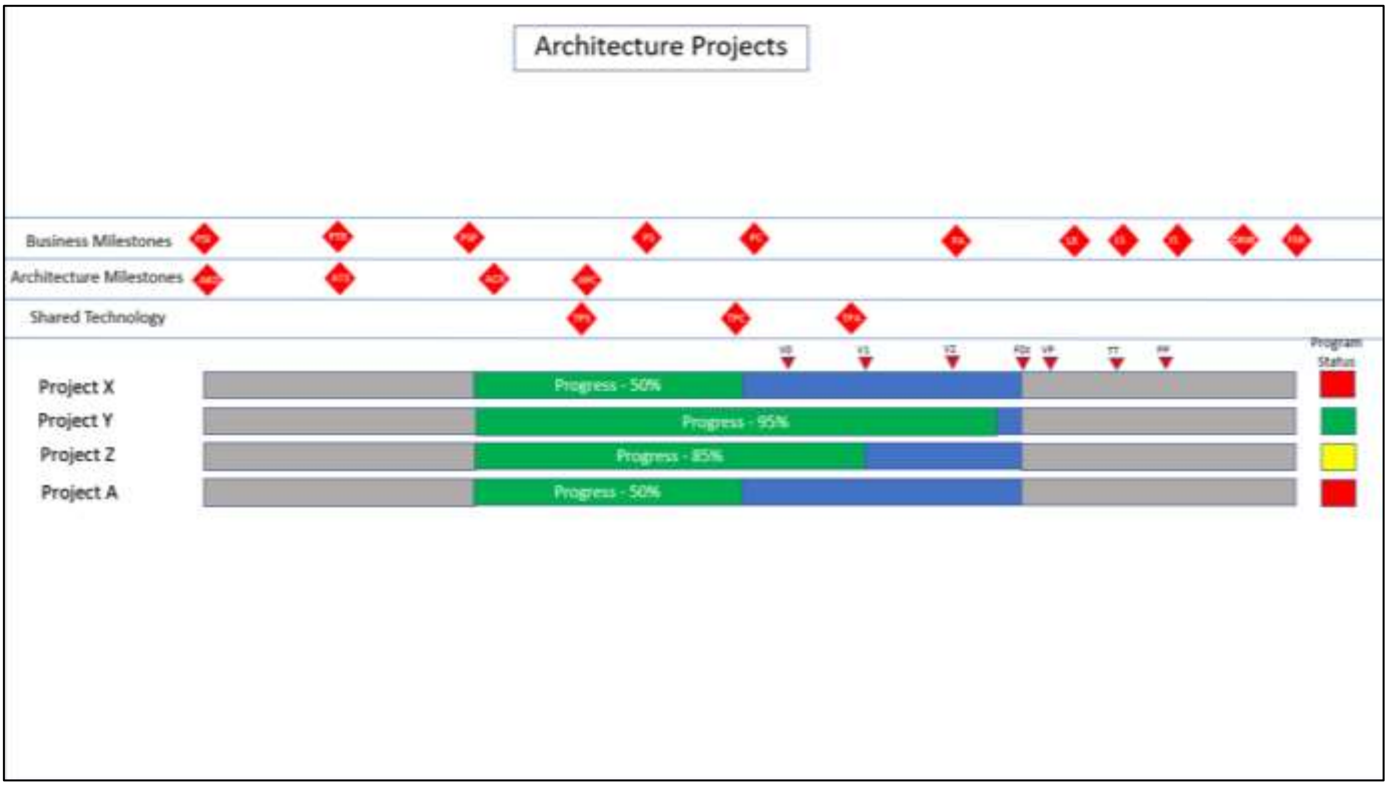


Figure 5.12: Overall PQSP Status

The figure above provides a good visual indicator of where the project is with regards to the milestones and gateways that CEVT uses throughout its projects. For example, in the picture it can be seen that project X is currently at the TPC milestone, however, it has only achieved 50% of its target IPTV score whereas it should have achieved 95% of the target according to CEVT's estimate. This is indicated by a red box next to the progress bar. This is what needs to be brought to the attention of the attendees of the level 1 meeting: What gate the project is at and how is the progress. IPTV scores and issues do not help them make decisions.
The tool can be provided with drill-down capabilities. In case the management needs a deeper dive into the project, the project can be selected, and the tool will take them to a page which shows the overview of the particular project as shown in figure 5.13. The contents of this dashboard have been shown in three different ways: The glide path, the top five issues of the project and their details and a Pareto chart.

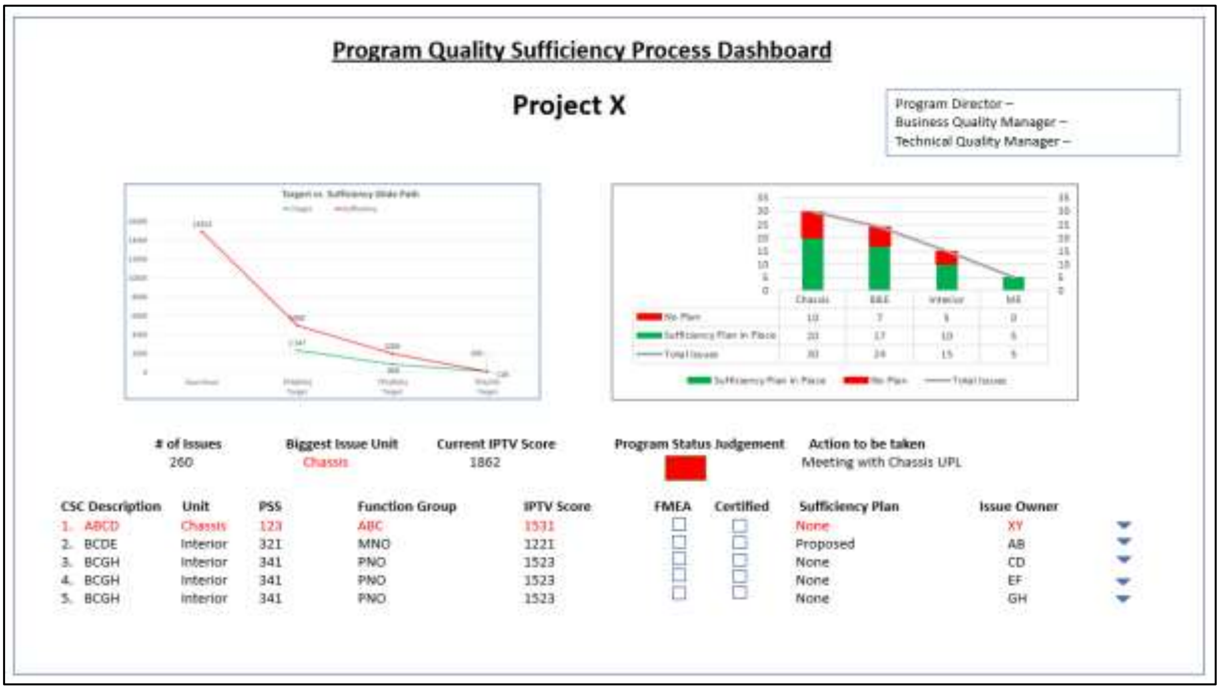


Figure 5.13: Project X PQSP Status

The glide path is the standard glide path used by CEVT. However, the proposal is that the dashboard must show the top five existing issues that the project has for which sufficiency plans have still not been proposed. A long list of all the issues will not be useful to the decision makers and project teams. The topmost issue is what requires the most attention at that particular point and needs to be resolved. The line also provides the viewer with the information about which unit, PSS and function group the issue belongs to, the IPTV score, whether or not it will be solved using FMEA and which engineer is the owner of the issue.

The additional proposal is the use of the Pareto chart as shown. The Pareto principle or the law of vital few states that for events, approximately 80% of the effects come from 20% of the causes. This chart uses the Pareto principle to focus the management's attention on the unit which has the highest IPTV score, i.e. the unit which needs the most attention. The columns are shown in the decreasing order of issues which have no sufficiency plan. The chart also has a table showing the units total issues and the number of issues with no sufficiency plans. Below the chart is a line which shows the status of the project in general. It shows how many issues the project has, what the biggest issue unit is, what the current project IPTV score is, what the program status judgement is (Red, green or yellow) and the action to be taken. The ‘Action to be taken’ has been proposed to encourage the presenters of the dashboard to come up with the ‘what-next’ action recommendation rather than come to the meeting expecting a decision to be taken by the decision maker. It encourages proactive thinking.

This dashboard can also be drilled down to address the attendees of the level 2 and level 3 meetings where more deep-dive is required. The PQSP status of each unit can be shown as shown in the Pareto chart except for the fact that the chart shows the statuses of the individual PSS that belongs to that particular unit. Further drill down is possible to see the PQSP status of a PSS with the Pareto chart showing the status of the individual function groups belonging to the PSS. The individual function groups can also further drill down to see the issues that belong to them and what issues need to be focussed on immediately. The dashboard is always live, hence the Pareto charts are continuously refreshed to show the focus area at that particular time.

5.3.4 Case 4: Functional Maturity

5.3.4.1 Process Description

A vehicle project at CEVT is split into multiple functions that make up the car. For example, ‘Steering’ is a function which is handled by one function team belonging to a unit. ‘Distribute Fuel’ is a function handled by another function team belonging to another unit. These functions have to develop the parts they are responsible for in order to make sure that their function can be implemented in the actual car in the manufacturing phase. One of the ways these functions are tracked is by the usage of documentation to ensure that the functions have plans to implement their functions within the project. This plan has detailed information of what maturity level their functions will reach at what phase in the project. The responsibility of PDQ is to ensure that the documentation is made available at the time they are supposed to and also to ensure that the functions have reached the planned maturity stage at the right time in the project.

5.3.4.2 KPI Analysis and Visualization

As stated, the responsibility of the PDQ is to ensure that the right documentation is completed and submitted at the right time. They also ensure that all the functions in the project have reached the level of maturity they need to be at, at a certain time in the project. This is followed-up using a functional follow up tool where all the functions report their progress. CEVT has a dashboard that visualizes this information. However, it has some of the associated risks described in section 3.2.2 (Risks of a Dashboard). The dashboard can easily misinterpret the information that is provided at the functional follow up tool. There is no system in place to track the validity of what is reported. The tool has certain flaws that cannot be highlighted by the dashboard. For example, one of the columns in the tool is a date at which a certain activity needs to be done. However, it does not indicate if the date is as planned or delayed since the system does not know the target completion date. Hence, there is no way to identify if a function will not be ready at a time it is supposed to be ready and when that information eventually becomes available to PDQ, it might already be too late.

5.3.4.3 Dashboard Prototype

In order to have a good dashboard, the data behind the dashboard must be trustworthy. The data for the dashboard comes from the function follow-up tool. Hence, this section also contains improvements for the tool/database.

Presently, the follow-up tool has the functions mapped to their PSS. However, they have not been mapped to the units. For the dashboard to be viewed at the level 1 meetings, it is suggested that the dashboard be shown at the unit level since a drill-down will be too much information for the attendees of the meeting. It is also suggested that, for proactivity, the functions be asked to enter the expected submission date of the documents. It serves a good purpose to have the fixed target visible on the tool at all time. Two weeks before the deadline, the date could appear in yellow font to indicate an approaching deadline and once the deadline has passed, the date could be shown in red font to bring about a sense of urgency.

With regards to monitoring, if the functions are at the right maturity status at the right time, a potential improvement is when the functions have to indicate their maturity status. There are two columns in the tool, the 'Required Status' and 'Actual Status'. It is suggested that the actual status be indicated in red if the actual status is below the required status. This makes it easier to differentiate between the functions which are at the correct maturity status and the ones which are not. Currently, the tool has a column which asks the functions to enter the actual date on which they will verify if their functions are at the right maturity status. The functions have an option to either enter the date or leave it blank. Also, there is no indication of whether the date is in line with the timeline of the project or if it is delayed. Hence, the suggestion is to add a column that indicates when the verification is supposed to be done. In the future, it is suggested that the system automatically derives this date from the function plan. When the functions think that the forecast verification date will be delayed, the date is shown in red to indicate that the function is delayed and will not reach the correct maturity at the right time.

The dashboard suggested to visualize functional maturity consists of three charts. The first chart indicates what maturity all the functions are at. The second chart indicates a unit-wise split up of all the functions which are at the correct maturity stage, the functions which are below the correct maturity status and the functions which have not yet reported the status.

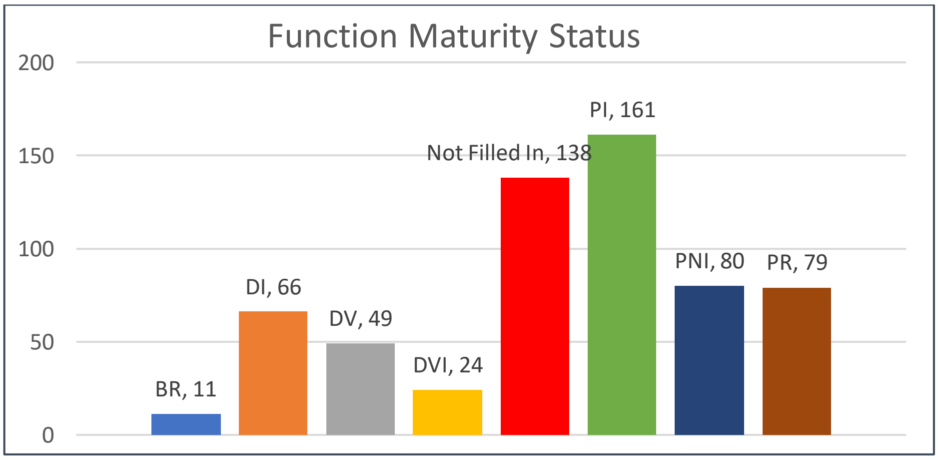
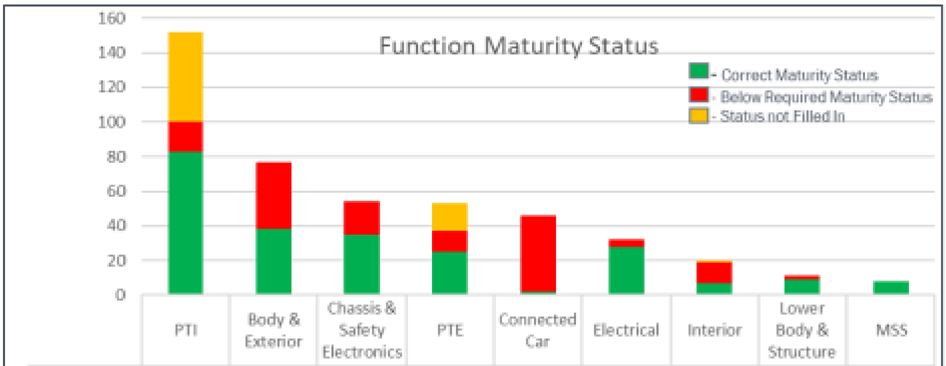


Figure 5.14: Function Maturity Status



	PTI	Body & Exterior	Chassis & Safety Electronics	PTE	Connected Car	Electrical	Interior	Lower Body & Structure	MSS
Not Filled In	52			16			1		
DVI		1			21	2			
DV	2	29			17	1			
DI	15	9	19	12	6	1	1	2	
BR							11		
PR	17	33	6			9	2	9	
PI	66	5	29	25	2	19	5		8

Figure 5.15: Unit-wise Function Maturity Status

Both the charts show the functions that have not reported the maturity statuses. Additionally, the second chart shows which maturity statuses the different functions are at. However, the overall status is indicated only by three colours.

The third chart on the dashboard is created to proactively indicate to the user of the dashboard which functions will not reach the required maturity status on time. The information is taken from the previously proposed "Planned verification date" and "Actual Verification Date" columns. If the actual verification date is later than the planned verification date, it is shown in the chart below. This allows the decision maker to deep dive into the functions and view what the problem is and try to solve it in order to help them reach the maturity status on time. The chart also indicates which of the functions will not reach the maturity required for vehicle testing. With this information, the testers can know which functions they do not need to test. It is speculated that this data could save a significant amount of time and money.

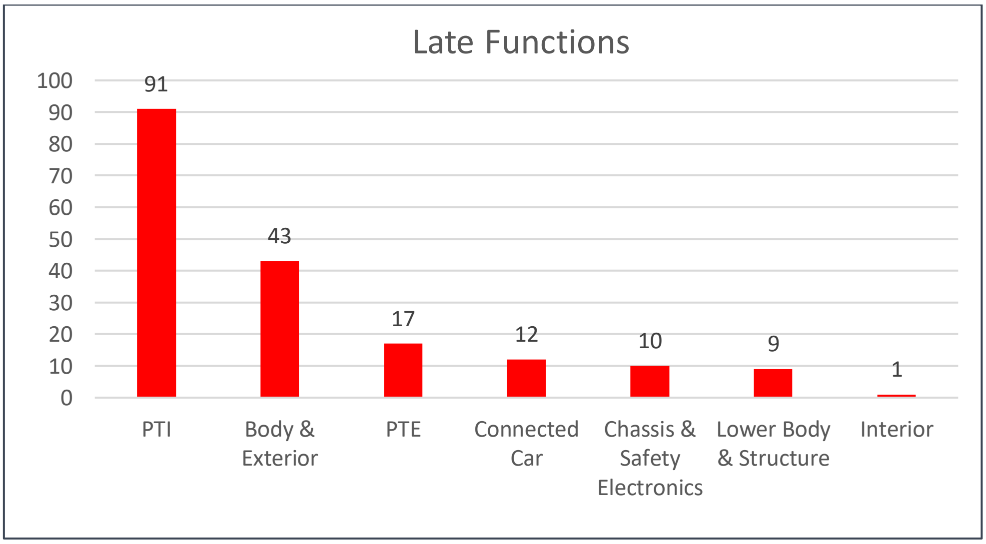


Figure 5.16: Functions that are Late in Reaching the Required Maturity

5.3.5 Case 5: Risk Management

5.3.5.1 Process Description

A risk, as defined by CEVT, is a potential cause for concern that will have a negative impact on the business with respect to cost, time of completion and quality. Every aspect of a project that is deemed to be a cause for concern is documented in order to be escalated to the upper level of management. It brings the risk to their notice and propose an action if a decision needs to be made. Risks can be owned and reported by any business unit involved in the project. They do not deal with product risks themselves, but with the project risks reported by any business unit. Once the risk is documented and judged for its severity and impact to the business, the PDQ works to follow up on these project risks and ensure that these risks are handled before the completion of the project.

5.3.5.2 KPI Analysis and Visualization

The KPIs connected to risk management in projects are the number of risks themselves. This number by itself provides the performance indicator for a project. Higher the number, more is the business concern. Of these risks, a real risk to CEVT are the risks which cannot be handled on time. These risks are documented in a tool called the risk list tool. The risks are reported with respect to severity of the risks (Rated 1, 2, 3, 4 and 5), their impact to the project (Rated Critical, Major, Moderate, Minor and Monitor), their probability of occurrence (High, Medium and Low) and also with respect to the meeting to which it needs to be escalated (Level 1, 2 and 3). The risk list tool also has an option for the risk owners to indicate that they will not be able to solve the risk at the expected time. However, there is no visual indicator that highlights them for the management. All these aspects will have to be considered while visualizing the risks on a dashboard.

5.3.5.3 Dashboard Prototype

The first part of the dashboard represents the split up of the risks in terms of project, severity, risks and impact levels. This is required in order to judge which risks are required to be shown at the different levels of meetings. This information is visualized as shown in the figures below.

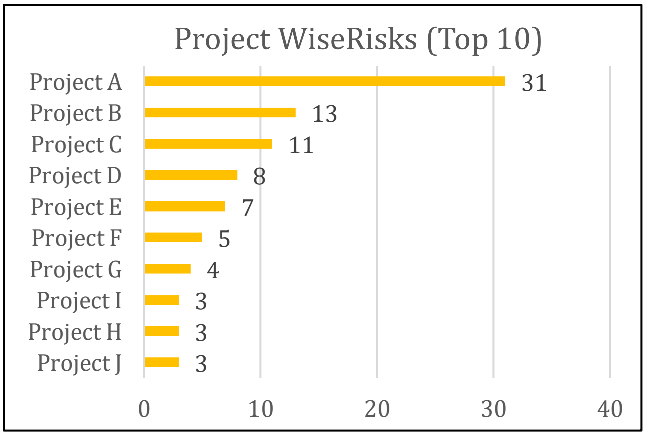


Figure 5.18: Project Wise Risks

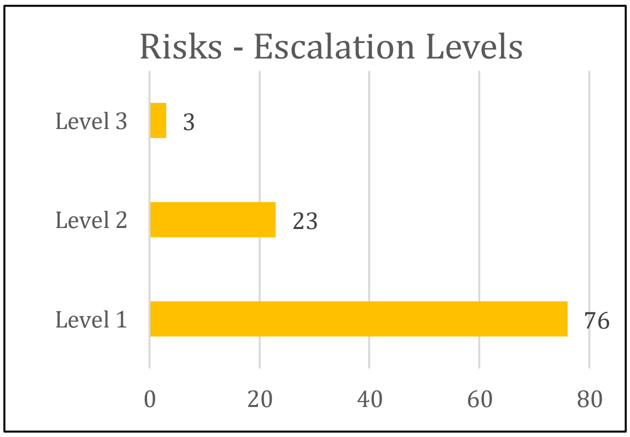


Figure 5.17:Risks by Escalation Levels

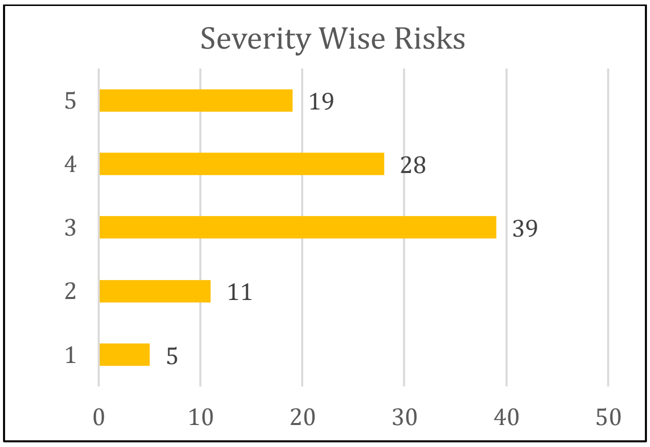


Figure 5.20: Risks by Severity

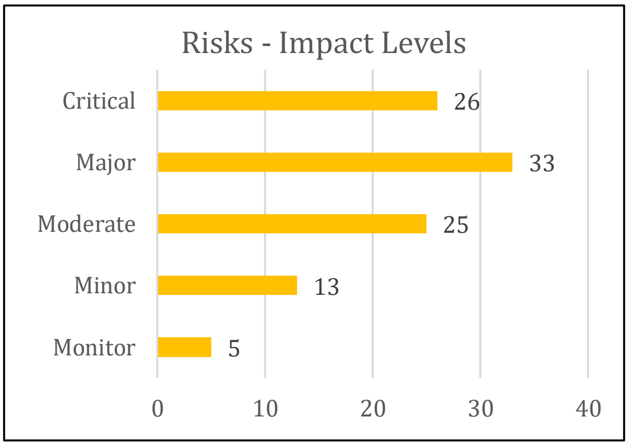


Figure 5.19: Risks by Impact Level

The charts above provide an overview of all the projects at CEVT. However, they can also be filtered to see project wise classification of risks. This could be useful for all the levels of the meetings and for the project teams.

From interviews with the potential users of the dashboards at the different levels of meetings, the important KPIs which need to be visualized were gathered. It was decided that only the important risks which will have a significant impact will be shown. Hence, a chart indicating only the critical and major risks was designed as shown in figure 5.21. This chart provides the split-up of the risks among the different units, PSS and function groups. However, a filter is also provided to show the risks other than critical and major. Hence, this chart caters to the needs of all the levels of the meetings due to its ability to be customized.

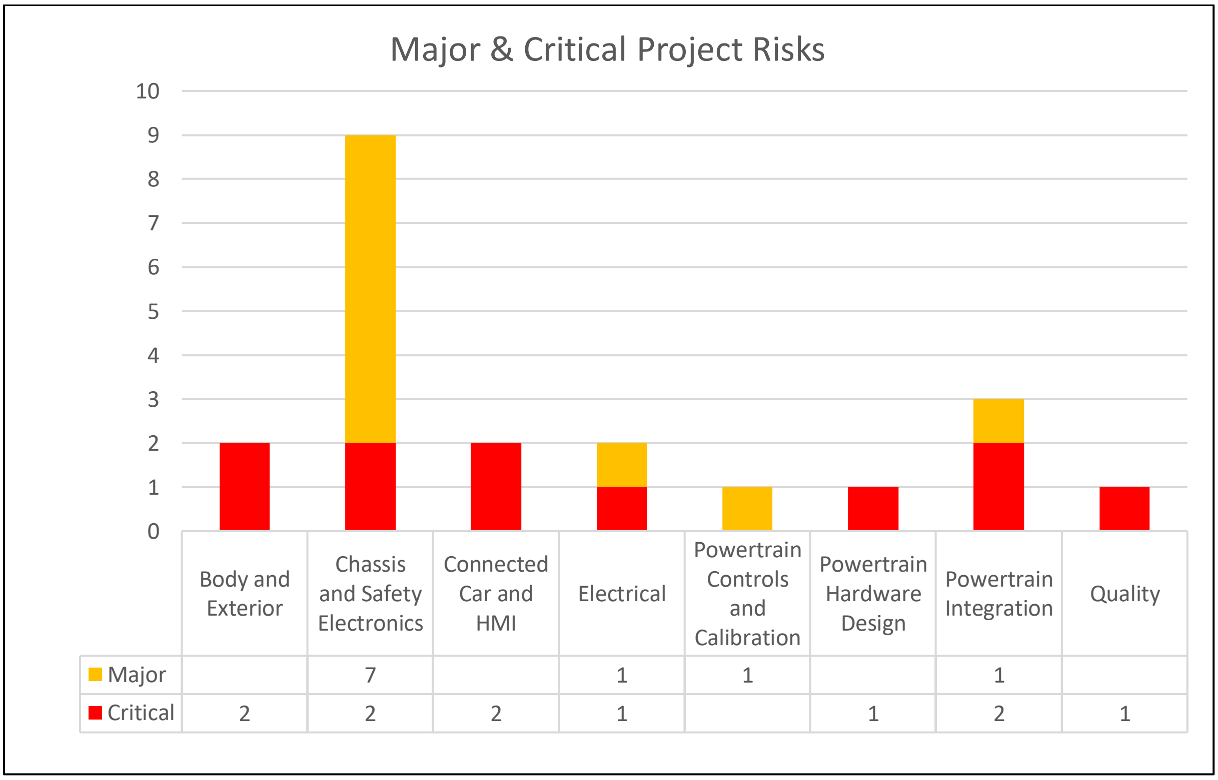


Figure 5.21Major & Critical Project Risks

Although it seems like all the important information could be provided by the chart above, the thesis discovered another KPI that could potentially provide more information to the decision makers. As previously stated, the risk list tool has an option for the risk owners to indicate if the risks will be solved at the planned time or not. If they think they will not be able to solve the risk on time in the future, they can forecast the risk to be a “red risk”. Presently, this information is not visualized, it is only indicated within the risks. However, it was found important to visualize it in the dashboard.

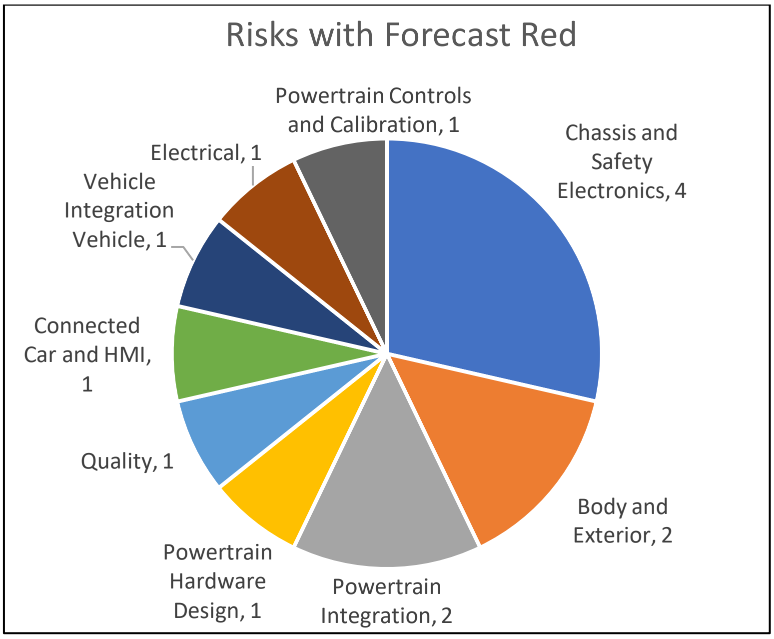


Figure 5.22: Chart showing unit-wise split up of forecasted red risks

The above chart shows a unit-wise split up of the red forecasted risks. This is useful information for the top management as well as the unit leaders and it urges them to look into these risks immediately. This was validated by both interviewee 2 and 4 who said that they liked to see the visual indicator for showing the risks with red forecast since it is very important to bring to attention.

5.3.6 Case 6: Overall Summary Dashboard

Although the individual process dashboards presented above provide useful information regarding the respective processes, a good visual indicator would be one which summarizes all these processes and provides the necessary information to the upper management in a single page. Such a summary dashboard has been suggested in the thesis. This is especially helpful for level 1 and level 2 meetings where the upper management would only like to know if everything is on track or if there are any risks for which decisions need to be made (Section 5.1.1). Two types of overall dashboards have been proposed in this section: One addressing the attendees of the level 1 meeting and one addressing the attendees of the level 2 and 3 meetings.

The first dashboard is designed to be shown at the level 1 meeting. Here, the top management of CEVT including the CEO of CEVT attend the meeting to view the overall progress of all of CEVT’s projects. In order to address this, the progress of all the projects are shown in a single page as shown in figure 5.23.

Quality Dashboard

Quality Processes / Projects	Project A	Project B	Project C	Project D	Project E	Project F	Link to Tool
Program Quality Sufficiency Planning	NA	●	●	●	△	●	Link to Tool
Design Reviews	△	△	●	△	●	△	Link to Tool
Part Validity	●	●	●	●	△	●	Link to Tool
FMEAs	△	△	●	△	●	△	Link to Tool
Risk Management	●	✖	●	●	△	✖	Link to Tool
Lessons Learned	✖	△	●	✖	●	△	Link to Tool
Functional Maturity	●	✖	●	●	△	✖	Link to Tool
System Safety	●	●	●	●	●	●	Link to Tool
Homologation	✖	△	●	△	●	△	Link to Tool
Quality Reliability Testing	●	●	●	●	△	●	Link to Tool
VQRR/PQRR	△	✖	●	△	●	✖	Link to Tool
PAD/CTC	△	✖	●	✖	△	✖	Link to Tool

● - On Track
△ - Delayed with an action plan
✖ - Delayed with no plan

Figure 5.23: Overall CEVT Quality Dashboard

As can be seen in the picture, the dashboard provides the necessary information regarding how all the projects are doing with regards to the different processes. The visual indicators used are both shapes as well as colours. Red indicates a delayed process that needs management attention, yellow indicates processes that are delayed but the team members have a plan to get it back on track at the target time and green indicates a process that is on track. The different shapes have been used considering attendees of the meeting with colour-blindness. The last column provides a link that takes the page directly to the process dashboard in case the management wants to deep dive into the process. This is especially useful when there is a process that is indicated in red. The management will generally want to know the reason behind it being red and hence, a link to the process dashboard would come in handy.

The second type of dashboard is calibrated for the attendees of the level 2 and 3 meetings who would like to know the progress of the individual processes for every project. Hence, the dashboard is a summary page of the "vital few processes" that the presenters of the meeting want to talk about (As shown in figure 5.23).

Figure 5.24: Project Quality Dashboard

The dashboard shows the vital few processes, the current status, the forecast status to the next milestone/gateway, a summary of the processes and the actions that are being taken or going to be taken. Apart from this, value addition is done by providing an overall project status and the forecast status to the next milestone/gateway. The status provided on these dashboards are presently filled manually according to what the presenters of the meeting judge the status to be. It is difficult to provide a fixed status judgement for the processes since there are no documented ways of identifying the status of most processes and hence, the statuses have to be reported in good faith for now. The summary column summarizes the information displayed by the dashboards. The summary and the actions columns are particularly important when the forecast status of the processes is deemed to be red. The management would be really interested in understanding the reasoning behind the red status and what actions are going to be taken to avoid it or set it back on track. When management involvement is really needed is when the overall forecast to the next milestone/gateway is red, especially towards the end of the development phases.

5.3.7 Relationship between the KPIs

During the study of the current performance measurement at CEVT, it was found that the different quality processes of CEVT worked in silos and hence looked into their own performance measurement and developed dashboards. However, certain dependencies were revealed between two KPIs while conducting the studies. Hence it was interesting to investigate the relationship between the existing KPIs to see if one KPI influenced the performance of another KPI. A focus group study was conducted to determine the relationships.

The results of the relationship study are as shown in figure 5.25.

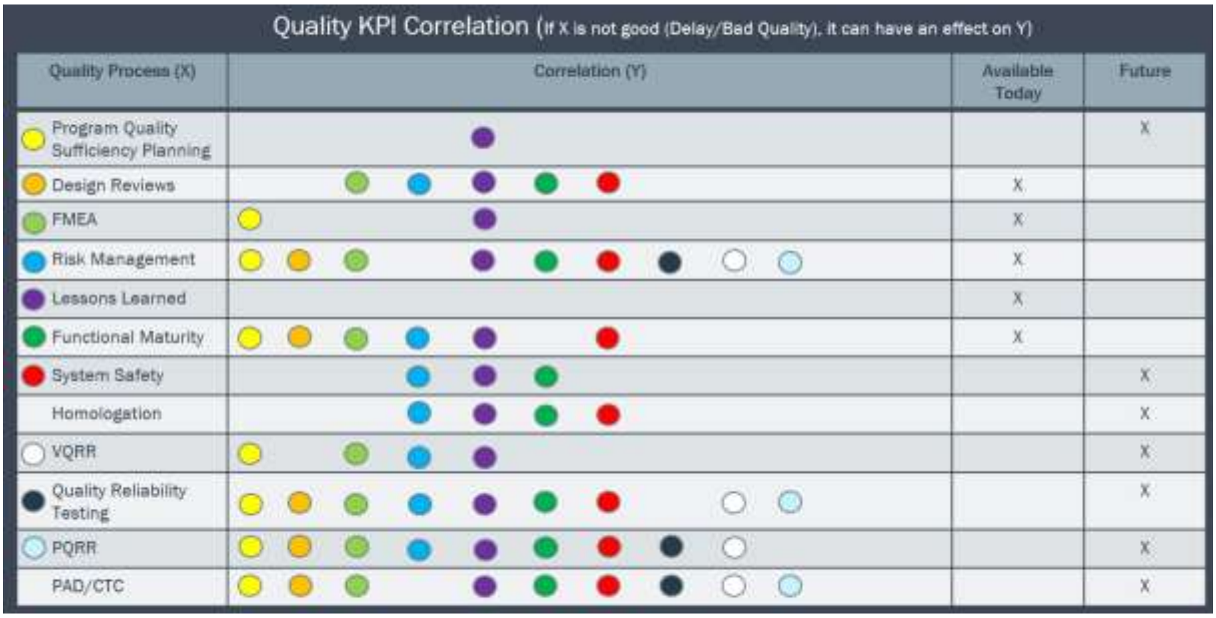


Figure 5.25: KPI Relationship Study

In the figure above, the quality processes are colour coded to show their relationship with the other processes. It was found that a lot of the processes directly or indirectly influenced a lot of other processes.

One example of the relationships is with regards to design reviews. It was discovered that the design reviews connected to a lot of the other KPIs. As mentioned in section 5.3.2, design reviews have a lot of deliverables listed in them that have to be done on time. Some of these deliverables were found to be the quality processes that PDQ monitors. For example, design reviews have a section which ensures if FMEAs have been done on time. Hence, if the FMEA status is not considered to be on track then there will be a delay in approving the design review. There is a similar situation with regards to the function maturity process. If functions are not at the right maturity at the right time, the design reviews cannot be approved. Hence, it could be concluded that if design reviews are monitored well, all the other quality processes will perform well and can be secured on time. Another example is the relationship between functional maturity process and the vehicle testing process performed at the end of the product development phase. If the functions are at the right maturity level before testing, then the testing team will not discover issues. However, if the functions are not ready, the testers will discover issues which will be passed on to the engineers who already knew that the function will not perform well at testing. This saves significant time and money.

Using the relationships uncovered from the study above, the dashboards were created, and process improvements have been proposed. Although only some of the relationships could be implemented on the dashboard, the study, however, helped raise the awareness among the team of the dependencies of the different processes on one another. Thus, the study is recommended by the author to be treated as an important pre-study to be done before designing the dashboards.

6 Discussion

Upon the completion of the thesis, the agreement of the results with the literature study was analysed and certain conclusions were made. The dashboard framework developed by Pauwels et al., (2009) could benefit from more theory. What is suggested to be included is the study of the type of dashboards required in the supply side of the framework. While designing the dashboards for all the process, a pattern was recognized which identified three types of dashboards that as conducive to decision making: Qualitative dashboards, quantitative dashboards, and dashboards that encourage proactivity.

6.1 Qualitative Dashboard

Qualitative dashboards are one which provides the performance measures without the use of numbers. In certain management decision styles such as experience-driven decision style, numbers do not matter as much as gut feeling. Decision makers go with the trust in their employees. One example is the overall summary dashboard where the performance measurement is done using shapes and colours. These symbols are placed on the dashboard by the managers following their gut feeling about their progress. There is no standard set of rules that describe the placement of the symbols except for the meaning that the symbols carry. If the presenter of the dashboard feels that the process is on track, he/she places a green symbol. If they feel the process is delayed but they have a plan to get it back on track, the yellow symbol is used. If they feel that the process will not be completed on time and they have no plans, it is judged to be red. The author of the thesis finds this to be acceptable since this allows a certain level of autonomy for the managers to run the process. It encourages the top management to place trust in the managers and allows the managers to provide their input without a system judging their process (Section 3.2.5). This prevents the possibility of cheating the system. Hence, in situations where a gut-feeling based performance measurement can be made, a qualitative dashboard is perfectly acceptable to be used. Other examples of these dashboards are the project summary dashboards and the PQSP dashboard which also requires the presenter to judge the status.

6.2 Quantitative Dashboard

Quantitative dashboards provide performance measurements with the use of numbers, charts, and graphs. In the case of data-driven decision-making styles, a quantitative dashboard is what generates credibility in performance measurement. In these situations, numbers communicate the progress much better than words and symbols. These types of dashboards are seen in most of the dashboards designed in the thesis. Well-designed graphical representations provide a good visual indicator that makes it easy to grasp the necessary information. Examples from the thesis are the FMEA dashboards, function maturity dashboards, risk management dashboards, and design review dashboards.

6.3 Proactive Dashboards

While designing all the dashboards, it was considered useful to always look into possible forecasting scenarios. Sometimes, they prove to be more useful than a dashboard that can only provide the as-is condition. Such dashboards encourage employees to think about the consequences of their decisions. It also proved to be useful while designing the functional maturity dashboard. It uncovered the relationship between function maturity and the vehicle testing processes. Proactive dashboards help with keeping up with the target, especially in projects which span over a long period of time. Examples of such dashboards can be found to be a part of the FMEA, function maturity and design review dashboards.

6.4 Alignment with the Literature Study

While the results and analysis section of the thesis agreed with the theory suggested in the literature study, for the most part, there were certain deviations that were encountered while designing the dashboards. For example, the dashboard development stages suggested by Pauwels et al., (2009) mentions the dashboard metrics' connection to financial consequences as part of its steps. This proved to be a difficult task while considering some of the metrics. However, it was found that the metrics had consequences for the internal customers in terms of time and resources used. When performance measurement is done appropriately, the internal customer down the line in the project benefitted from it with respect to time and efforts which had a direct consequence on the finances. Hence, an indirect connection to the financial consequences were found although the consequences could not be quantified. The metrics, however, could easily be connected to external customer satisfaction as suggested in the same development step.

One of the stages also involved forecasting scenarios, i.e. discovering the what-if analysis as a way for managers to evaluate all the options available and take well-informed decisions. However, in the case of CEVT, there was no possibility of providing options and forecasts that would drastically change the direction of the project. What was more useful to have as a dashboard item was a what-next analysis. Hence, a modification was made by replacing the what-if analysis with what-next analysis.

The two schools of thought, InfoVis vs. Statistical Graphics played an important role in the designing of dashboards. While both the schools of thought put forth valid points, it is quite difficult to follow just one since all the principles of that school cannot be practically applied in the industry. In statistical graphics, emphasis is laid on numbers and charts like scatter plots, box plots, etc. which are said to provide good information using low ink-to-information ratio. However, outside of the academia, such charts are difficult to understand and utilize. In InfoVis, it says the information must be visualized in a way that tells a story. Less emphasis is laid on numbers. The dashboards have been created taking the best of both schools and combining it. The numbers in the dashboards have been given importance along with providing visually pleasing charts that are easy to understand by the industry (Column charts, pie charts, etc.).

Another part of the literature study that proved to be extremely useful was the technology acceptance model. The terms "Perceived Usefulness" and "Perceived Ease of Use" have been considered while designing the dashboards. TAM encourages involvement of stakeholders while creating the designs. Hence, the potential users of the dashboard and the upper management have been involved in the making of the dashboards. The prototypes have been tested in the different levels of the meetings and have been accepted. TAM is a highly recommended model to be used while designing dashboards.

Overall, the theory used in the thesis proved to be extremely useful in the development of the dashboards. The theory did not just provide information regarding the design of dashboards, but also implementation and adoption of the dashboards resulting in a successful end-product that was perceived useful and easy to use by the end customers.

7 Conclusions

The purpose of the thesis is to provide the basis for selecting actionable KPIs and visualizing these KPIs using dashboards for effective decision making. This chapter has been included to answer the research questions. One conclusion that is important to be made is that the content of this report, although focussed more on automotive product development, can be generalized to other industries. Pauwels et al., (2009) puts forth a framework which is all inclusive with regards to the essentials of a dashboard including the necessity of drill-down capabilities that satisfy multilevel stakeholders. The development stages used by them also prove to be a good checklist to be used while developing effective dashboards. Considering this, the research questions are answered as follows:

- *RQ1 – What to consider when choosing actionable KPIs for multilevel stakeholders?*

Five factors are to be considered while choosing actionable KPIs and designing dashboards to visualize these KPIs: Demand, Supply, the fit between demand and supply, implementation process and the predisposition of users. Uncovering information about all the factors provides the designer of the dashboard with a lot of details to consider when choosing the actionable KPIs.

Demand:

Firstly, one must consider the users of the KPIs. Answer the questions: Who is going to use the KPIs? What are their intentions with it? Investigate the general organizational decision style. If the decision-making is data-driven, numeric KPIs with proof of solid data analysis is required. However, if the decision-making is driven by experience and gut feeling, numerical KPIs will not be used appropriately. KPIs must also be chosen keeping in mind the common benefit to all the departments. KPIs that are only useful to one part of the organization are not the most effective ones. They can easily be misused by other departments. Decision needs to be made regarding whether a generic approach of KPI selection can be applied to the organization or if a tailored approach needs to be taken to satisfy the organization.

Supply:

Investigate what metrics are available to indicate performance. Understand how the organization wants to view the KPI and decide between providing KPIs in the as-is form, what-if form or what-next form. Choose KPIs that make sense for all the levels of hierarchy in the organization (Multilevel Stakeholders). The KPIs can be customized to have drill-down capabilities which can make sense to all the levels of the hierarchy.

Fit between Demand and Supply:

The fit between demand and supply is critical for the success of a dashboard. The KPIs presented must be relevant for the users of the KPIs and must help decision makers make decisions. The KPIs must reflect the strategic orientation of the organization. Always refer to a success map while given the task of selecting KPIs. A success map provides information about what KPIs are really important for the organization as a whole. It helps the designer take a holistic perspective on KPI selection and ensure fit between demand and supply.

Implementation:

For the entire organization to be on board with the KPIs selected, the users of the dashboard must be involved in the selection. This is emphasized by the technology acceptance model. If the users themselves are involved in KPI selection, they feel responsible while using them to measure performance. Implementation must include prototyping, testing and continuous feedback and updates to the KPIs. The final KPIs will only be selected after several cycles of testing and feedback. Inadequate implementation will result in only a part of the organization appropriately utilizing the KPIs which indicates the imminent death of the KPIs in the long term.

Predisposition of the Users:

Selection of KPIs that have ensured a good fit between demand and supply and has been implemented correctly will instantly cause the users of the KPIs to have faith in the use of the KPIs. The decision makers will also trust the KPIs that is shown to them. This results in successful adoption of the key performance indicators.

- *RQ2 – How to develop an effective dashboard for decision making?*

Using the five dashboard development stages put forth by Pauwels et al., (2009), the author answers the research questions as follows:

Stage I: Selecting the Key Metrics

The key metrics must be selected using the framework provided above. The information uncovered while trying to answer the questions posed by the demand and supply boxes gives the dashboard designer a lot to consider while choosing the actionable KPIs. One must ensure a fit between demand and supply using the technology acceptance model to get the users to have faith in the metrics. This will ensure that the dashboard is used effectively in a way that it is intended.

Stage II: Populating the Dashboard with Data

While developing this stage, the dashboard must be populated only with content that will be useful to the potential users of the dashboard. This will also be ensured while applying the technology acceptance model to this stage. Continuously involve the potential stakeholders of the dashboards while populating the dashboard. As previously indicated, complicated charts and graphs that cannot be easily understood at a glance must be avoided. In the industry, simplicity of information goes a long way in helping the users easily understand the content. In this way, decisions must be taken to adequately populate the dashboard. Principles of data visualization prove to be helpful at this stage. These methods can be observed in all the dashboards designed by the thesis.

Stage III: Establishing Relationships Between the Dashboard Items

As proved by the results of this thesis, most processes are directly or indirectly related to one another. Understanding and visualizing the effect one dashboard item has on another will go a long way in helping the users acquire a system view of delivering their work. Apart from this, the different items on the same dashboards can also work together to provide useful information. For example, refer to the percentage completion pie chart, table and the column chart used to visualize the current status. Together, the charts provide information of the current status and also the target.

Stage IV: Forecasting and Scenarios

Stage IV involves discovering the what-if analysis as a way for managers to evaluate all the options available and take a well-informed decision. However, if required by the organization, the what-if analysis could also be replaced by a what-next analysis. This potential to do wonders goes unrealized in most situations since most firms only focus on metrics that explains the current status of operations (Pauwels et al., 2009). For example, refer to the PQSP dashboard (Section 5.3.3). The dashboard does not just present the as-is condition of the process, but also allows the presenter and viewer of the dashboard to think about what actions need to be taken with regards to the current status.

Stage V: Establishing consequences to Internal and External Customer Satisfaction

Establishing the consequences to both kinds of customers could lead to the users benefitting in terms of time, efforts and money saved and could also connect the dashboard items to the end customer satisfaction. For example, the functional maturity dashboard indicates issues that saves a lot of time for the testing team which comes later in the project. When there is a possibility to connect the metrics directly to financial consequences, it must be done so. Financial consequences are good indicators of the consequences of the decisions made.

8 Future Work

The purpose of this chapter is to suggest how the research done in this thesis could be further developed. It also includes addressing the limitations of the thesis and suggestions to break out of the limitations.

Firstly, it has been established that the results of this thesis will be for the benefit of the PDQ department of CEVT. However, the dashboards created are considered to be useful for the entire R&D organization apart from just the quality department since most of the processes are executed by them. Once the dashboards have been established for the entire organization of CEVT, the dashboards can also be proposed to the parent organization (Zhejiang Geely Holding Group) to align the two organizations in terms of KPI visualization.

One of the most important future work would be to identify different ways of working to better use the database system that is presently being used. The effectiveness of the dashboard is determined by the data behind it. In some dashboard cases, requirement of more data and suggestions to better use the data has been explained (For example, requirement of expected completion date of design reviews (Section 5.3.2)). Hence, continuous improvement of the data and the database will lead to a continuous improvement of the dashboards. Continuous improvement of data also means looking into the quality of data, data gaps and requirement of more data that better suits the performance measurement of that particular process.

It is also suggested to periodically test the effectiveness of the dashboards and the data to see if different KPIs need to be measured other than what is currently being measured. This is due to the fact that organizations are continuously changing with time along with changing priorities. Hence, it is always good to take a step back to ensure that the KPIs that are being measured are still in line with the strategic orientation of the organization.

An important concept that was explained in the theory was the connection of KPIs to financial consequences. This was one of the stages of dashboard development. However, given the limited time available to conduct the thesis, this exercise could not be fully looked into. However, the author sees potential in this concept and feels that tremendous information can be uncovered if attempts were made to connect all the KPIs to their respective financial consequences. Even if the task is not possible to achieve, it will still raise awareness among the owners of the different processes and future decisions will be taken keeping in mind these newly discovered financial consequences.

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Appendix

Interview Questions

The interviews held for the multilevel stakeholders followed the pattern as shown below. Questions were asked based on the level of meetings that the interviewees attend.

Interview Purpose

Analysis of Quality KPIs in the Different Levels of Meetings

At each level people want to see different levels of information that they think will impact the business. Some KPIs influence the way they think and make decisions. Sometimes, the KPIs can work well in combination and provide a better picture for the decision makers to see the impact of their decision. Some of the KPIs that are currently in use could even be redundant. The purpose of the interview is to analyze the performance measurement to see if CEVT is doing them in a correct manner. In order to show the effect of the KPIs the dashboard is necessary. The goal is to identify the necessary KPIs and create a dashboard to show all the KPIs in an adequate manner.

While answering, please try to think of how it should be instead of how it is now. Think big.

Name:
Role:
Working since:
What meetings do you attend and what roles do you take (Responsible, Accountable, Support, Inform)?
Ans:

General Questions about Meetings (Lesser Detail)

1. What are your basic expectations from meetings and how long would you like your meetings to last ideally?
   Ans:

2. What is good information from your perspective?
   Ans:

3. What is bad information from your perspective?
   Ans:

Questions about Product Development Quality (Lesser Detail)

4. What are your expectations from:
   a. Level 3 Meetings in general and quality leaders in particular? (If a part of the meeting)
      Ans:

b. Level 2 Meetings in general and quality leaders in particular? (If a part of the meeting)
   Ans:

c. Level 1 Meetings in general and quality leaders in particular? (If a part of the meeting)
   Ans:

5. How much time would you like to spend understanding the:
   a. Project Quality
      Ans:

   b. Product Quality
      Ans:

6. What should KPIs within PDQ department indicate in your opinion? How do you measure progress in project and product quality?
   Ans:

<u>Questions about KPIs – Current State Analysis (Go into detail)</u>

7. Do you feel that the Quality KPIs that are currently being presented to you informs you of all the information you need to know? What is the percentage of useful information that is shown to you in

   a. Level 3 Meetings (If a part of the meeting:
      Ans:

   b. Level 2 Meetings (If a part of the meeting):
      Ans:

   c. Level 1 Meeting (If a part of the meeting):
      Ans:

8. Among the list of information given below, which of them would you say are key performance indicators? Rate them with “Very Important”, “Important”, “Unimportant”, “Unnecessary/irrelevant to the meeting”. Please add any other Q KPI that is missing.

KPIs	Very Important (Must-be)	Important (One dimensional)	Unnecessary \Irrelevant to the meeting	Which level of meeting ?	Relationship with other KPIs	Comments
1. PQSP						
2. Design Reviews						
3. FMEA						
4. Project Risk Management						
5. Lessons Learned						
6. Functional Maturity						
7. System Safety						
8. Homologation						
9. VQRR						
10. Quality Reliability Testing						
11. PQRR						
12. PAD/CTC						

9. Do you feel the information given above would be sufficient to understand the progress and make decisions?
   Ans:

<u>Future State</u>

10. What additional information\KPIs do you feel you need to get the full picture and make effective decisions? In essence, what is your ideal dashboard?
    Ans:

11. What are your expectations from my thesis with regards to the Quality KPIs and dashboard?