Internal Supply Chain Performance Management & Measurement Systems: Design for Implementation

The Case Study of VDL ETG

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Abstract

"Supply chain versus supply chain" is the new mantra for contemporary competitive businesses. To reach the desired competitive advantage and sustainability, companies are acknowledging the importance of supply chain management and the benefits of improving it by performance management and measurement systems. Combining supply chain management to these performance systems into a supply chain performance management and measurement systems should enable enterprise quest in becoming business differentiators. There is a large gap in literature when it comes to merging these two concepts, so this research aims at bridging this gap, providing a case study within the high tech industry. A supply chain performance management system framework is developed, together with a supply chain performance measurement system and the intent is to create awareness for further validation and development. The deliverable is the design for implementation of a KPI dashboard which incorporates the frameworks established, providing a high level integral overview of the case company's performance allowing Management Team members to know where to focus and allocate resources in order to improve and ultimately reach their vision.

Keywords: Supply Chain Management, Performance Management System, Performance Measurement System, Supply Chain Performance, Key Performance Indicators, High Tech Industry

1. Introduction

Globalization, new business models and an empowered customer and workforce have accelerated the pace of business beyond what seemed possible just five years ago [1]. Because accurate and appropriate performance evaluation is critical for judging the success or failure of a business, performance indicators that accurately reflect the competitiveness of a company must be carefully identified. Business to business (B2B) supply chains (SCs) are increasingly taking center stage in the quest for greater profits and competitive advantage [1]. [2] concludes the following: companies that acknowledge SC as a strategic asset achieve 70% higher performance and the ones that beat the competition on supply chain (SC) performance also reach significantly better financial results. Henceforth, effective supply chain management (SCM) is treated as key to building a sustainable competitive edge through improved inter and intra-firm relationships [3].

Continuously improving SC performance has become a critical issue for most suppliers, manufacturers, and the related retailers to gain and maintain competitiveness [4]. To carry out this constant performance development, one must always acknowledge the following two aspects of performance *per se*: performance management (PMa) and performance measurement (PMe). Accordingly, and bearing in mind the well-known quote by Peter Drucker "you can't manage what you can't measure", PMa and PMe are not separable. They follow one another in an iterative process; management both precedes and follows measurement, and in doing so creates the context for its existence [5]. In other words, performance management systems (PMSs) encompass performance measurement systems (PMeS), but not the other way around [6].

Incorporating SCM and performance management & measurement systems (PMMSs) into supply chain performance management & measurement systems (SCPMMSs) should catapult enterprise revenue and contribute extensively towards a business differentiator. In view of this, one would expect interest in developing management and measurement systems for managing SCP to be escalating, however, and as acknowledged further in this research, current literature lacks an adequate framework for the design of SCPMMSs and empirical cases of adoption experience are extremely limited in academic literature.

A suitable environment for a pragmatic case could be the high technology (high tech) industry since the nature of competition in this manufacturing industry has changed dramatically over the last two decades, and any of the traditional indicators of business performance are insufficient today [7]. Furthermore, in order to maintain their competitive edges in the market, high tech firms cannot simply rely on superior technology alone [8]. For this reason, the high tech industry context presents itself as being particularly interesting for developing SCPMMSs as an empirical case. Paring this fact with the interest in investigating how this industry could take advantage of SCPMMSs to catapult its competitive position, presents enough incentive for this research.

1.1. Research Objective

This research aims to contribute to current academic literature by filing in the gap between SCM and PMMSs, which can serve as a basis for further theory development in the high tech industry. Configuring the supply chain to meet the needs of individual customers has proven to be a winning formula [2]. Hence, the research does not aim to build a one-size-fits-all framework since PMMSs should always be derived from companies' specific vision and mission, which is clearly different for each firm [9]. Instead, it intends to define a tailored design of SCPMMSs and the configurations associated with its implementation. Findings are based on a case study within VDL Enabling Technologies Group (ETG). This research will provide the case company with the best approach to the design for implementation of internal SCPMMSs that drive value maximization for the customer at the lowest possible cost.

2. Literature Review

2.1. Supply Chain Management

The term SCM was originally introduced by consultants, in the early 1980s yet, there is no consensus as to the exact meaning of SCM since there are many definitions of SC and, consequently, SCM [10]. For the purpose of this study, the

following definition by [11] was chosen; it defines SCM as a "systematic, strategic coordination of the traditional business functions and the tactics across them, within a particular company and across businesses within the supply chain, for the purposes of improving the long-term performance of the individual companies and the supply chain as a whole". Within this definition, a SC is defined as "a set of three or more entities (organizations or individuals) directly involved in the upstream and downstream flows of products, services, finances, and/or information from a source to a customer." Although many other attempts to define SCM have been made, they are not as encompassing as this one [12].

Dynamics of faster product development set new expectation standards and traditional managerial attributes are being revised to improve firms' competitiveness in this new environment [13]. Organizations began to realize that delivering the best customer value at the lowest cost is not only related to the activities functions and processes within the organization itself, but to the whole of the supply chain [14]. It is suggested in literature that traditional competition of company versus company is changing towards a business model where SCs compete against SCs [15]. This is because as much as a product or service itself is important to a firm, an effective SCM strategy can assist a company with an established and sustainable competitive advantage, if well executed [16].

2.2. Performance Management System

[17] defines PMa as actions, based on PMe and reporting, resulting in overall improvements. According to the United States Office of Personnel Management [18],"PMa includes:

- Planning work and setting expectations;
- Continually monitoring performance;
- Developing the capacity to perform;
- Periodically rating performance in a summary fashion;
- Rewarding good performance."

Variety on different perspectives and frameworks concerning dimensions for managing performance is limited, especially when narrowing PMSs to the SC point-of-view. Whilst reviewing literature, three PMa frameworks were established; Framework 1 –[19] upgraded [20]previous 5 'what' questions to 10 'what' and 2 'how' questions, Framework 2 –[21] developed a PMS specific for the SC context, and last, Framework 3 –[22] proposed the management cycle.

2.3. Chosen Performance Management System Framework

All frameworks underline the significance of a top-down approach, where the first step is identifying the vision and mission of a company in order to set goals. Additionally, all frameworks follow to some extent the structure of the Plan-Do-Check-Act cycle. This makes sense since the structure is popular when one wants to control and continuously improve processes and products.

On the other hand, the frameworks have their own unique elements and to make this clear, Table 1 offers a clear summary and comparison of all frameworks in terms of key characteristics acknowledged from their advantages /disadvantages. Framework 1 is a general PMS outline whereas frameworks 2 and 3 are specific for a SC context. For this reason, frameworks 2 and 3 take advantage in comparison to framework 1 because when adopting such a structure, one must always take into ac-count the context in which the framework will be applied or studied. Thus, opting for a PMS that is specific to the SC context over one that is very generalist is ideal. The descriptive characteristic refers to the extent to which the end user of the PMS framework can follow the structure and content of the several steps of the system.

Table 1: Comparison of all Performance Management System Frameworks

Characteristics	Framework 1	Framework 2	Framework 3
Specific		x	x
Descriptive	x	x	
Info Sharing	x		x
KPI Feedback			x
KSFs	x		

Since researchers suggest that closer information-based relationships become an enabler of effectively managing SCs which seek improved performance through effective use of resources and capabilities [23], this characteristic was taken into account when comparing all the PMS frameworks. Framework 2 lacked this feature meanwhile the other two made a highlight for information sharing. One of the strongest points for framework 3 is the existence of a KPI feedback loop, which the other frameworks fall short of. And last but not least, the contemplation of key success factors (KSFs) provide extra strength for framework 1 since it is an essential aspect for awareness creation in enterprises at the initial stage of designing a PMS framework that should enable improved performance of their SC.

To sum up, and in view of all these observations, the conclusion drawn is that there is no framework that is perfectly adjustable to the context of this research. The semiconductor industry, and more specifically, VDL ETG, with its distinctive practices of high-mix and low-volume, should consider all the characteristics from the above table when developing a PMS framework for superior SC performance in order to gain competitive advantage, by outperforming the market. The complexity of this market makes it compulsory to have a PMS that incorporates all the aspects mentioned, and with this in mind, this research will not follow one of the frameworks identified by review of literature. Henceforth, a new framework was established, including all the important attributes stated, and therefore resulting in a mixture of frameworks 1, 2 and 3. The chosen framework is described next.

Figure 1 schematizes the chosen PMS framework for driving overall performance of VDL ETG's internal SC. It is composed of all the strongest points and characteristics of the three frameworks analyzed above. By this, it should provide the best theoretical design of a SCPMS and the several steps for implementation.

2.3.1. Step 1: SCPM Function

By identifying the SC's vision and mission for the case company, the main goals of SC and SCM are derived. Once these goals are well-known, a certain performance for those goals can be set up. It is crucial to create awareness of these objectives to all stakeholders that are in some way linked and involved - directly and indirectly - in this process. Then, the key success factors should be established in order for them to serve as an enabler of future SC success.

2.3.2. Step 2: Diagnosis and Analysis

Diagnose the AS-IS (current) situation and then the desired TO-BE scenario, followed by the identification of the existing gaps between both states of affairs. Lastly, the gaps that will be addressed must be pointed out, to clearly state what the company wants to improve.

2.3.3. Step 3: Action Plan

Specific solutions to help meet the performance goals and close the gaps should be made into a roadmap; moreover, identification of 'what' and 'who' is affecting performance is a must. Milestones have to be developed to track progress.

2.3.4. Step 4: SCPMeS

A SCPMeS is established in this phase, with the purpose of being able to quantify the SC performance. To do this, SC KPIs must be identified.

2.3.5. Step 5: SCPMS

Monitoring growth and performance levels are executed by this step. Correct resource allocation is carried out, based on the review and improvement of growth, to improve SC performance. The company should also execute benchmarking activities to compare their performance with fellow companies. Finalize the step by consolidating reports.

2.3.6. Analyze KPIs

This step represents the KPI feedback loop present in framework 3 and it is taken into account for this PMS framework because of the dynamic characteristic present in the SC context. It is placed between the last step and returns to the initial one, since updates are made and new goals are derived. Here one must define and establish the relationships between the existing KPIs, studying how one KPI affects another, as well as updating them. Analyze KPI accomplishment comes subsequently, followed by cost calculation, covering all costs involved in the accomplishment. Lastly, improvement patterns may be identified.

2.3.7. Information Sharing

Through the establishment of both internal and external connections aligned compatibly with system-wide objectives [24], organizations shift from arm's length to an integrated range of possible relationships [25], thus creating a flawlessly coordinated SC that is a potential source of competitive advantage [14]. In view of this, including information sharing on the chosen PMS framework is seen as vital, hence it was included.

2.3.8. Contextual Factors & Culture

Framework 1 strongly emphasizes the inclusion of the contextual factors and culture of the company at stake. Organizational culture, a notable contextual variable, pervades the entire control system influencing choices and behaviors of individuals [4]. So the study and understanding of the operation of the control system benefits from the consideration of the impact of culture [4]. This presents enough reason for the inclusion of these aspects, taking them into account on every step of the PMS framework.

2.4. Performance Measurement System

PMe is often defined as the process of quantifying action [26], where measurement is the process of quantification and actions lead to performance. [26] states that PMe has several objectives like creating focus, it represents the basis for evaluating performance, triggers corrective actions, and may help challenging and improving strategic choices. Hence, selection of metrics and targets are therefore seen as concrete formulations of the firm's strategic decisions [27].

PMeS executes PMe in a consistent and complete way where it is a balanced and dynamic system (software, databases, procedures) enabling decision-making by gathering, elaborating and analyzing information [28].

A number of PMeS frameworks have been developed since 1980s [29]. The Supply Chain Council's Supply Chain Operations Reference Process Reference Model, the Balanced Score Card, and the Strategic Measurement Analysis and Reposting Technique (SMART) pyramid are three of the most referred PMeSs in literature and the most used nowadays. These frameworks have their own relative benefits and limitations. Literature review indicates that empirical and theoretical validity of some of the frameworks are established whereas information about others is not available

2.5. Chosen PMeS Framework

Six balance requirements which need to be addressed when developing a PMeS were identified from literature. With these requirements, one can assess the quality of the three frameworks mentioned above and choose the best model (theoretically). The framework containing all or most of the requirements is indicated as the best suit. After analyzing, it is derived that the SMART pyramid supports all requirements as so for this reason, it is seen as the strongest framework and is chosen. It is a simple and concrete approach, simple to comprehend. SMART's strength is in vertical integration between strategic, tactical and operational level as well as horizontally within these levels.

Figure 3 represents the adapted SCPMeS framework, based on SMART pyramid. Since the context of the research is SCM, some modifications were made to the original pyramid. *Vision* becomes the *SC vision*, where the strategic course of the company's SC is set. At the second level, objectives are

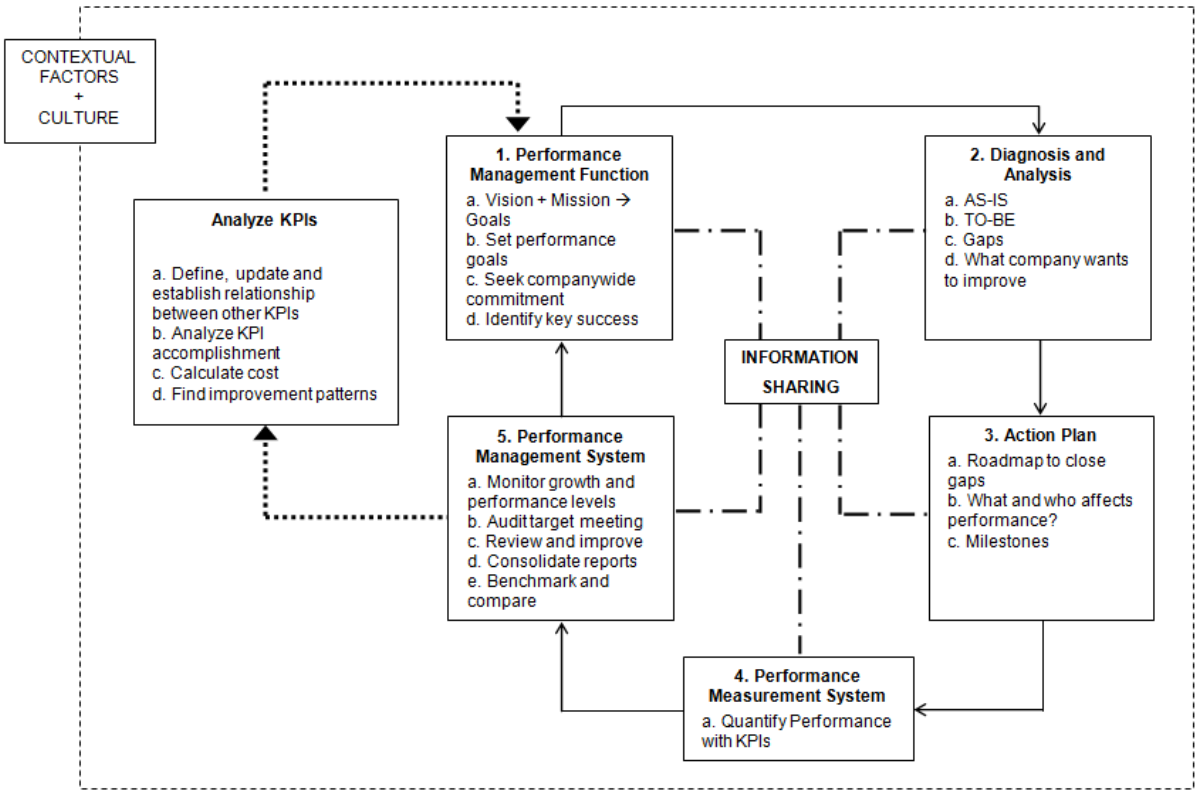

Figure 1: Chosen Supply Chain Performance Management System Framework

defined in financial and non-financial terms: *total cost of ownership* and *customer value*, instead of *market* and *finance* respectively. This is because the ultimate goal of this research is to provide an integral SCPMS whilst maximizing customer value at the lowest total cost, based on the SC Strategy in focus for the case company. *Customer value* represents long term goals for value generation levels and identifying what customers are willing to pay for the products the company supplies. On the other hand, *total cost of ownership* refers to the long term financial goals and how internal results impact this aspect.

Moreover, successful companies compete on three fronts: customer satisfaction, flexibility and productivity [30]. On this tactical level, instead of just considering the aspect of *productivity, cost* was added on top of. *Customer satisfaction* is assessing the management of customer expectations, *flexibility* evaluates the responsiveness of the process/system to change, and *cost and productivity* appraises if resources are effectively managed, focusing on costs. Since it has increasingly become a major concern for the case company, giving a bigger emphasis on *cost* is a requirement and there are more types of costs that must be taken into consideration that are not related to *productivity*. *Flexibility* affects *cost and productivity* negatively whilst in terms of *customer satisfaction* the effect is positive, so it is strategically positioned in between these aspects.

On the operational level, not much changed. Since the context of this research is the high tech industry, *technology* is vital and most associate it with *quality*, hence the merging of these two aspects into the block that was originally just *quality*. The primary goal is to meet customer expectations through delivery of defect-free products and/or services meeting all technological requirements. The last modification is related to the block *cycle time*. To include this original aspect would be to limit the scope of *time*, where cycle time is an example of a KPI. *Reliability* assesses whether the case company delivered what the customer requested. *Waste* is all the non-value-adding activities and resources needed for meeting customer requests.

Since this framework is integrated within the chosen PMS framework, at the base of the pyramid lays the *Information Sharing System* where information accuracy, availability, timeliness and sharing are reviewed. Without an effective and efficient information system, data cannot be collected, analyzed and interpreted so it presents itself as a condition for performance improvement.

The strength of this framework is the integration level of services as an added value for the customer [30]. *SC vision* will determine the ultimate goal, where *customer value* and *total cost of ownership* are the strategies applied for meeting this goal. Through *customer satisfaction, flexibility* and *cost & productivity*, these strategies can be met. *Quality & technology, delivery, time* and *waste* are the enablers of these tactical aspects.

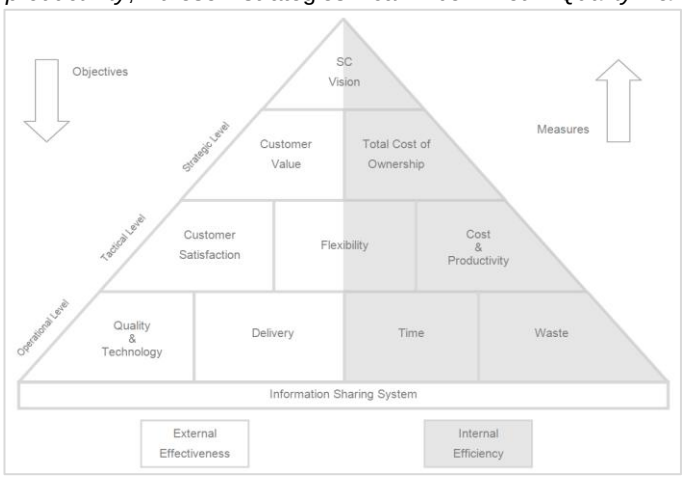

Figure 3: Adapted Supply Chain Performance Measurement System

3. Data Collection, Analysis and Interpretation

The AS-IS situation regarding SCP measurement at VDL ETG in terms of what KPIs are currently being applied was assessed and compared with the TO-BE scenario. The later identifies the ideal combination of KPIs that would ultimately enable the vision to be met. All ideal KPIs are placed accordingly to their corresponding category in the chosen SCPMeS. This scenario was built based on the theoretical KPIs and management team (MT) members' necessities.

Once comparison between AS-IS and TO-BE SCPMeS was completed, identification of the gaps amongst them was identified. Two big gaps were recognized in the AS-IS KPIs in use at the case company: no specific KPIs to identify performance levels on the categories of customer value and flexibility. These gaps are considered high priority gaps to be closed, hence all focus is directed at them. An attempt to close these gaps is developed by the implementation of three new KPIs; relation and wallet share to fill the gap of customer value and dual sourced products to close the flexibility gap. These implementations allow the final SCPMeS to be constructed (Figure 2) with all categories containing at least one KPI.

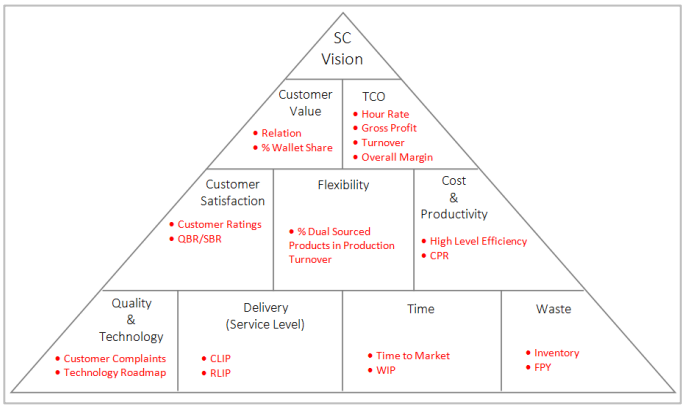

Figure 2: Final SCPMeS

3.1. KPI Definitions

3.1.1. Relation – Customer Value

How customers perceive relationship with VDL ETG.

3.1.2. Wallet Share – Customer Value

Percentage of spending from customers that is made at VDL ETG for the specific products/services it offers against total spent.

3.1.3. Hour Rate – Total Cost of Ownership

Average hourly cost of operations.

3.1.4. Gross Profit – Total Cost of Ownership

Net sales minus the cost of goods sold.

3.1.5. Turnover – Total Cost of Ownership

Total sales.

3.1.6. Overall Margin – Total Cost of Ownership

Average of margins of complete modules.

3.1.7. Customer Ratings – Customer Satisfaction

How customers rate VDL ETG based on quality, logistics, technology and cost.

3.1.8. QBR/SBR – Customer Satisfaction

Assesses if quarterly/strategic business reviews are in place with customers.

3.1.9. Dual Sourced Products – Flexibility

The percentage of capable dual sourced (make or buy) products/items in total production turnover.

3.1.10. High Level Efficiency– Cost & Productivity

Wage hours compared to realized hours.

3.1.11. Cost Price Reduction – Cost & Productivity

Percentage of on target cost price reductions agreed with customers.

3.1.12. Customer Complaints – Quality & Technology

Number of customer complaints.

3.1.13. Technology Roadmap – Quality & Technology

Percentage of targets met according to the technology roadmap's targets.

3.1.14. Confirmed Line Item Performance – Delivery

Measures the percentage of deliveries fulfilled according to the confirmed delivery date imposed by VDL ETG.

3.1.15. Requested Line Item Performance – Delivery

Measures the percentage of deliveries fulfilled according to the requested delivery date imposed by customers.

3.1.16. Time to Market – Time

Time span from conception of product until it is ready to be in a release for volume stage.

3.1.17. Work in Progress – Time

All items that are within production phases.

3.1.18. Inventory – Waste

Total inventory at VDL ETG.

3.1.19. First Pass Yield – Waste

Number of production orders that are not according to requirements the first time they are produced.

4. Design for Implementation

This phase of the research is structured according to the RADAR logic currently in place by the European Foundation for Quality Management on continuous cycle improvement. The RADAR logic is made up of four divisions: Results Target, Approach, Deploy, and Assess & Refine. The action plan to enable the design for implementation of the SCPMMSs at VDL ETG is described here.

The researcher, together with MT members and the company's thesis supervisor, came to the conclusion that, given the time frame of this research (8 months), the design for implementation will only cover the internal SCPMeS. Once this is accomplished, implementation of this system may proceed to then be incorporated into the chosen SCPMS (derived in Literature Review section).

4.1. Results Target

Innumerous meetings with MT members were established in order to identify their needs towards the design for implementation of the SCPMeS. The main conclusions drawn are as follows:

- MT members acknowledge the need for a clear communication tool that will serve as a facilitator of decision-making on a high level. To do this, an overall view of the high level KPIs should be provided where they can clearly identify how the company is performing.
- Such a tool that will be used in MT meetings with all MT members and the general director, so it must be extremely clear and contain an integral view.
- MT members expect to have insight on current information regarding the most recent data, but also find it imperative to have a comparison with historical data so that trends can be identified.
- It should be a flexible tool so that any change that may happen (for example: if MT members feel the need to add a high level KPI) can be easily implemented.
- MT members require an automated tool so they can focus on their day-to-day activities and not have to waste time updating this integral decision-making tool once a month.
- Definitions are important, so that everyone knows what is being talked about and this was a great issue shown by the MT members during discussions. To make sure that everyone is on the same page as to what data is being presented is key.
- Data accuracy was also a key point, so making sure that the extracted data is exactly what is needed is a must.

So taking into account the requirements presented by the MT members, the expected deliverable from the design for implementation is a communication tool that will facilitate MT members to make better decisions by providing an integral overview of how VDL ETG is performing and what really needs to be improved or receive a bigger focus.

4.2. Approach

After carefully analyzing all requirements exposed by the MT members and consolidating all the knowledge and information gathered and recognized up to this point of the research, an approach was developed. This approach aspires to respond to all these requirements and serves as the enabler to successfully attempt to answer the problem statement. The approach is described next, where a clear explanation as to how it will individually overcome the requirements is presented.

4.2.1. Clear Communication Tool for Decision Making Process

To respond to requirements regarding the need of a communication tool to support the decision making process, the approach is the establishment of a KPI dashboard with the chosen SCPMeS. This means that once MT members have their monthly meetings with the general director and must report on how their department is performing, they no longer need to do this separately with their own dashboards where the KPIs in place are listed and their status is identified. With the new dashboard, these meetings can occur with only one dashboard where an overall view is provided. This will be on a high level, since it is a requirement, so not all KPIs currently in place are included, just the ones derived from the final SCPMeS.

4.2.2. Overall View of Case Company's Performance

To make it a clear and visual dashboard, the categories that make up the pyramid should change according to their performance status. Their performance status will depend on the performance of the KPIs that make up each category. Since there may be some KPIs within a category that are more important than others (as to enabling the user to identify how the category is performing), there should be a weight factor given to each KPI which will then allow a more realistic overall status of the category. There should also be an overall speedometer to check the performance of the pyramid as a whole. So assessing how many categories are with a bad performance against the ones with a satisfactory and good performance to reach a final number that can classify the case company's performance. This provides the integral view of the company, one of the requirements from MT members.

4.2.3. High Level KPIs with Additional Information on Demand

The main aim of the dashboard is to provide the high level, integral view of the company's performance but the model should also be able to provide a one-step-deeper analysis to back up the high level view. This means that if a category in the performance pyramid is performing badly, and the MT

members want to focus on that category, the model should have information regarding why that specific category is performing badly. Data concerning which KPIs are within that category and their individual performance is important, together with all additional information needed.

4.2.4. Historical vs. Current Data

The interest revealed by MT members for the dashboard to provide a clear historical data view makes it crucial to incorporate this feature in the deliverable. To offer this, the previous month or week information should be exposed, together with the AS-IS information, permitting the users to compare both pyramids and clearly spot what has changed over time and where attention should be directed.

4.2.5. KPI Library

To grant the end users of the deliverable insight on what KPIs will be analyzed, a clear KPI library should be provided. This standardizes the information available of all KPIs and makes users aware of what is really being examined.

4.2.6. Automation

Regarding the automated required characteristic for the deliverable, in order to have such feature, one must treat data accordingly. This means that all data that should be extracted to the dashboard must be made available for all MT members, and for it to be automatically updated, it must be prepared for this. This presents itself as a real challenge since each department measures their own KPIs where data is extracted from MT members' personal files. This also means that there is no standard structure for these documents, making it difficult to automate.

4.2.7. Flexible

The flexibility factor can be incorporated into the dashboard by constructing it in such a way that if at any time an MT member decides to include one more KPI to a certain category, it is a feasible thing. Just like when the action is to remove a KPI or probably even change a category's name. These are all features that should be included in the dashboard if one wants to provide the best design for implementation.

4.2.8. Data Accuracy

Fighting the battle for data accuracy is challenging. All data should be extracted from the MT members' personal files where they track information regarding the KPIs that are in the final SCPMeS. Naturally, these files are connected to external sources of information, for example, the case company's business intelligence platform that is updated every night. This means that, if MT members have their documents linked to this daily updated information, data accuracy shouldn't be a problem. On the other hand, if this is not the reality, actions should be taken to make all data extraction connected to the business intelligence platforms and make data extraction an automated process.

4.3. Deploy

4.3.1. Model Structure

To start off the deployment process of the approach, one must identify its structure to then have enough insight for the deployment *per se*. Figure 4 provides the reader with a simple schematic diagram of the model's structure and all the different worksheets that make up the deliverable. The main view is, naturally, the dashboard, and all the other worksheets are considered supporting data for the dashboard. The links between worksheets represent information connections.

4.3.1.1. Main View

4.3.1.1.1. Ranking Procedure

For obvious reasons, the performance pyramid will be the spot light of the dashboard, where only the categories' names are visible and their fill is according to the KPIs' status. To establish the color ranking, discussions with MT members took place to analyze what rankings were currently in place at the

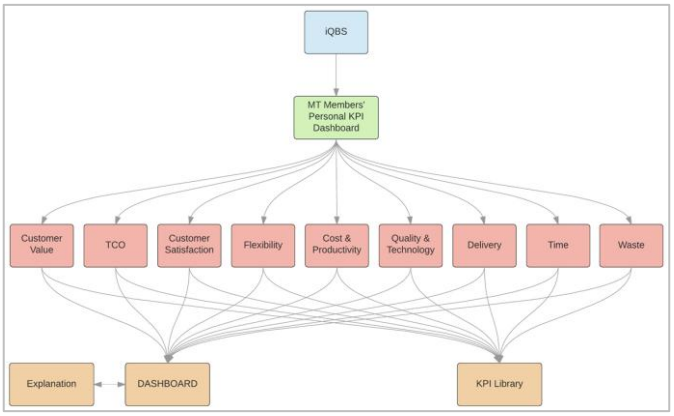

Figure 4: Dashboard's Structure

case company. The findings were as follows: there is a target, a lower and middle bound for each KPI and rankings (color and number) are based on this. If a KPI's performance is equal or above target, it is given a green color and a score equal to 4. If the performance is equal to the middle bound or better, but below target, it is given a yellow color and a score of 3. If the performance of the KPI is between the lower and middle bound, it is represented by the orange color and score equal to 2, and lastly, if the performance is equal to the lower bound or it is performing below it, is has a red color and a score of 1.

4.3.1.1.2. Speedometer

This ranking procedure will be maintained so MT members feel somewhat familiarized with the scoring of the performance and can easily and quickly relate to it. Once this ranking is established, the categories that make up the performance pyramid will be filled with either the color red, orange, yellow or green, according to their performance status. Since the categories can take up to 4 different scenarios, it is interesting to include, in the dashboard's main view, a table indicating how many categories are in the green category, yellow, orange and red. This table will then supply the information necessary to construct a speedometer. This speedometer should provide a final number that indicates the performance of VDL ETG as a whole. It ought to be included in the main view of the dashboard, where the result number is between 0 and 4 (0 being minimum score and 4 maximum) and the result is the weighted average of how many categories are in each color.

4.3.1.1.3. Update Process & Historic Comparison

One of the essential features to include in the dashboard view is a button that updates the information, as well as a button that provides users to compare historic data with current one. These will also be part of the dashboard's core view.

4.3.1.1.4. Data Availability

An indicator of the percentage of data available must be included in the dashboard's view since gathering all data from different external sources (MT members' personal files, business intelligence platform) and consolidating it into one document will not be easy. A new folder where only MT members have access to it must be created under the TQM domain and permissions will need to be issued for the researcher to have access to those personal files and data, so they can be extracted. This takes more time than one can plan so having this indicator of the data available is a must for the initial phase of the dashboard.

4.3.1.2. Supporting Data

Having identified the key elements that make up the dashboard's main view, the supporting data will now be described.

4.3.1.2.1. Explanation Sheet

It is imperative to have an explanation sheet concerning how the dashboard works. All assumptions that will take place must be described and explained here, as well as a brief description

of the performance pyramid and what KPIs are within each category.

4.3.1.2.2. KPI Library

Fulfilling one of the requirements presented by MT members, a KPI Library is a must. This should provide a concentration of all KPI information, using the template mentioned previously in this research. This guarantees that once definitions are made and incorporated into a document, when MT members are discussing these KPIs, they will be discussing about the same things. Confusions are avoided and everyone is on the same track.

4.3.1.2.3. Categories' Worksheets

This will be the main supporting data for the dashboard. When dashboard users are faced with a red category within the performance pyramid and want to go one step deeper as to understanding what went wrong, that category's worksheet will provide this. All categories' worksheets should include all KPIs within that category, as well as all data regarding them. The data in these worksheets will be linked to the performance pyramid in the main view of the dashboard to provide the right status color.

4.3.2. Model Construction

4.3.2.1. Step 1 – Build Category Worksheets

The first step to construct the dashboard is to start off by creating the worksheets for all categories of the performance pyramid. This step is entirely based on the SCPMeS and what KPIs belong to each category. The worksheets must include the category name, date, table with all KPIs that belong to that category and their data, the KPI template with definition, targets, owner, etc., weight factor table, and graphs with KPI performance against target.

4.3.2.2. Step 2 – Filling the Categories' Worksheets with Available Data

This step can be a real challenge when the data needed to be extracted is not in the correct extraction form. This means that the information has to be treated to then be automatically extracted to this worksheet. As stated before, this step requires the granting of permissions for the researcher to gain access to certain personal files. All permission requests were sent to the corresponding MT members, who would evaluate if they accepted to give permission or not. If yes, they would then send the IT change request to the IT helpdesk, who would perform this change. Taking into account that whilst this stage was in development, it was summer holidays season, which slowed this entire process, taking up to one month to get just one permission. In case the MT members were not willing to share their information, data was not made available.

4.3.2.3. Step 3 – Performance Pyramid Construction

Now that all categories' worksheets are ready with the available information filled in, the performance pyramid can be constructed for the dashboard's main view. This is a relatively easy step where the pyramid should be built with all the categories and the internal SC vision. Once the pyramid's structure is set, the next step is to extract the statuses of each category and filling the corresponding category with the status color, creating a strong visual impact on the performance levels.

4.3.2.4. Step 4 – Extracting Category Status to Pyramid

For one to successfully establish an automated way to extract the required information about each category to the performance pyramid (dashboard's main view), the safest procedure is using Excel Visual Basic for Applications. In view of this, a macro was developed to update the pyramid with the necessary information.

4.3.2.5. Step 5 – Build Speedometer

To construct the speedometer, a doughnut diagram was made together with a pie chart (pie chart in front of doughnut). Only half of both graphs are visible and the doughnut chart represents the ranking range, going from red to green with orange and yellow in between. The pie chart is the dial pointer that indicates the current value of the case company's performance.

The source of this data is the table located in the dashboard's main view with the number of categories per color. Red category has a weight of one, orange of two, yellow of three and green of four.

4.3.2.6. Step 6 – Historical vs. Current Data

To provide the users with a comparison view of the current performance pyramid and the previous month or week performance pyramid, a macro was developed. This macro will copy the current pyramid to the right hand side of the dashboard and create a new pyramid with the historical data on the left. Having both pyramids side by side will enable a clear comparison procedure for MT members.

4.3.2.7. Step 7 – Develop Other Supporting Macros

To support the correct functioning of the dashboard, there are some key secondary macros that needed to be developed.

4.3.2.8. Step 8 – Combining All Elements to Dashboard's Main View

Taking into account all of the above information, the dashboard can be constructed. Figure 5 provides de dashboard's main view, where users can instantly see the performance pyramid and the performance color of each category, the speedometer value provided by the table with the number of categories per color, the buttons to trigger the

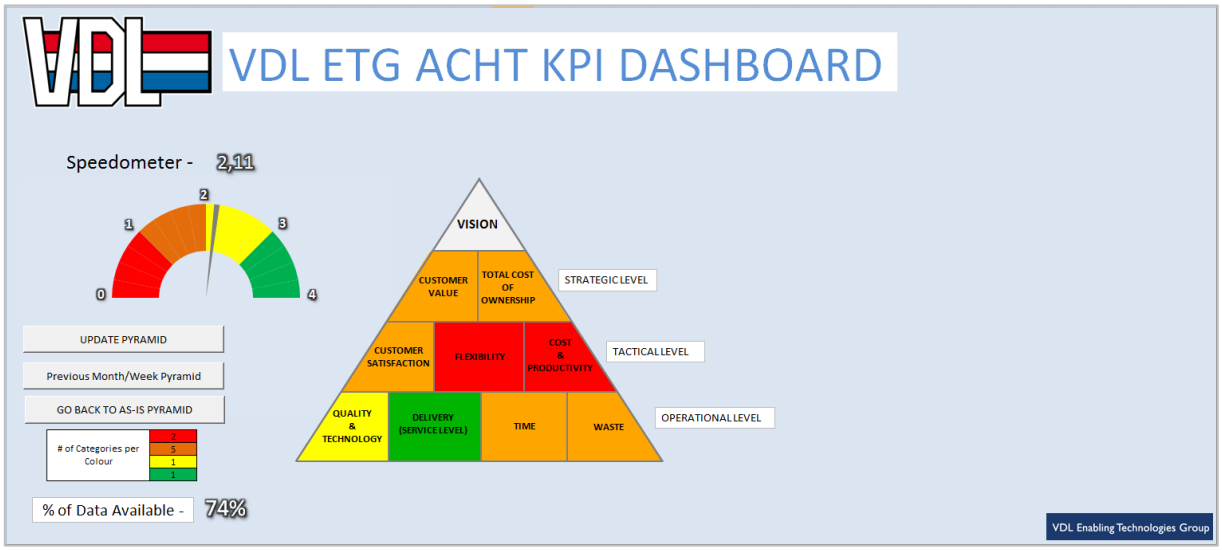

Figure 5: Dashboard Main View

update information macro, the comparison with historical data macro and the return to normal view macro. Percentage of data available is also in this view until this reaches 100%. This is the only feature that is manual, because it is a temporary characteristic of the dashboard's main view. As new data becomes available, this will need a manual adjustment.

This view is inspired in the general director's and MT members' favorable opinion on "Less is more". A very simplistic view that serves as the first point of contact document for the monthly meetings where further analyses are made based on this view. All categories have hyperlinks associated to them so to go to the corresponding worksheet, users just need to click on top of the category. Figure 6 provides the view of the dashboard when the historical data macro is triggered. The changes in performance that occurred in the interval of time are clear, meaning that the speedometer's value is going to change.

4.3.2.9. Step 9 – Establish KPI Library

This worksheet is where all the KPI information is consolidated. It is made up of all KPIs' templates and it is easy for the user to consult whenever necessary. All unavailable data is represented as a blue cell.

4.3.2.10. Step 10 – Develop Explanation Worksheet

To conclude the Dashboard Construction section, the reader should have awareness towards the explanation worksheet, the last remainder element of the dashboard. This worksheet is key to future users since it provides the necessary information for anyone to understand the dashboard. It starts with a brief explanation of the performance pyramid and lists all KPIs that constitute the pyramid. Information regarding the weight factors table and how it works is also found here, as well as the percentage of the available information provided by the dashboard at that moment.

The spotlight of the explanation worksheet is the macro information segment. All macros included in the document are mentioned and a brief description of their function is available. The flexibility offered by the dashboard model is then made known when a description of the steps to take when one wants to add or remove a KPI to a category are identified. All necessary alterations to the corresponding category's worksheet are identified so there is room for the new KPI information, as well as all the alterations required at the macros' level. This allows knowledge for anyone to be able to perform these changes.

4.4. Assess & Refine

The final step of the RADAR logic aims to identifying the results of the deployment and explain all alterations needed.

4.4.1. Assessing MT Members' Requirements

Establishing a clear communication tool was the main requirement, and to the opinion of the researcher, it was entirely fulfilled given that a centralized KPI dashboard was developed where meetings between MT members and the general director can occur with only one tool. The model provides an integral performance view where the chosen SCPMeS is integrated in it, making performance levels for each category very visual. Plus, the existence of the speedometer allows the integral performance to gain a general value. This value is dependent on the number of categories at each of the four possible colors. The colors of each category correspond to the weight factors and KPIs' status of the corresponding category. Given this, the integral performance view requirement is fulfilled. Table 2 provides a summary of all the requirements towards the deliverable and points out whether they have been fulfilled or not and how.

Table 2: Fulfillment of MT Requirements

MT Requirement	Fulfilled?	How?
Clear Communication Tool	Yes	KPI dashboard, 1 tool
Integral Performance View	Yes	Categories' color changes, weight factors, speedometer
High Level KPIs + One Step Deeper	Yes	High level KPIs with secondary information available
Historical vs. Current Status	Yes	Macro enables comparison view with two pyramids
KPI Library	Yes	Standardized info and templates
Automation	Partially	Most is automatic, some manual. Permissions take too much time
Flexible	Yes	Anything can be changed, and instructions to do so are provided
Data Accuracy	Partially	Hard when data source itself does not contain accurate information

The performance pyramid offers a very high level overview, where only the categories' names are visible with their corresponding color based on performance levels. For users to have access to more detailed information regarding why the category is performing as-is, a one step deeper analysis can be made by using the category's worksheet. This is where all information about the KPIs can be found, as well as their status. If users would like to go even one step deeper, then the owner of the KPI in question must provide additional information about the eventual PIs that exist, hence justify what has happened for performance levels of that KPI to be as-is. This requirement is considered fulfilled for all the above mentioned reasons.

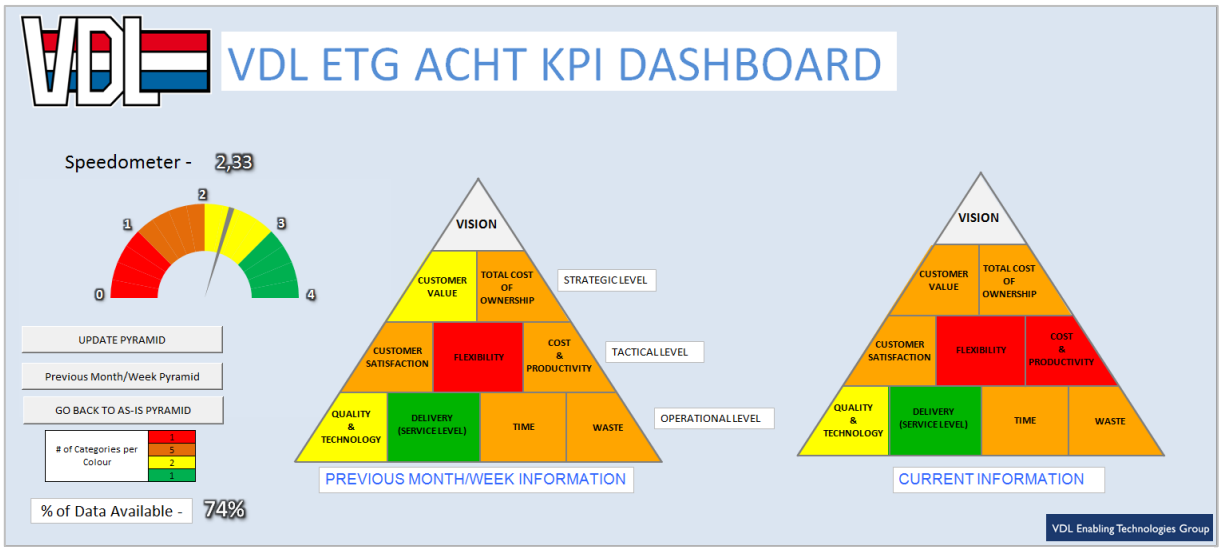

Figure 6: Historic vs. Current Data View

Historical versus current data is now accessible since the corresponding macro was developed and a simple button to trigger it was made available to users in the dashboard's main view. This enables insight towards the previous status of the performance pyramid and the previous speedometer reading. Users can easily compare both scenarios and draw further discussions from it. It is believed by the researcher that this requirement is fulfilled.

Regarding the existence of a KPI library, this is available but not all data is, since permissions to access this information were not granted or the waiting process was still active. The existence of such worksheet allows information to be standardized into templates, where all KPI definitions are provided, avoiding any confusion from this. It is very important that MT members discuss about the same things, and know what they are discussing. One could argue that given the fact that not all data is available to complete the KPI library, stating that the requirement is not fulfilled, but the structure is there and all available data is connected to this worksheet, leaving only the rest of the unavailable data to be filled in. For this reason, the researcher considered that this requirement is fulfilled.

Automation was one of the most complicated requirements to take into consideration because not all MT members' KPI dashboards have the automated characteristic. Especially the relatively new KPIs that have less than one year (example: high level efficiency). When permissions were granted to gain access to the right folders, automation was developed to extract the correct data to the centralized model. Given all of the above, and attending to the fact that there is one KPI that requires manual input to be updated, the automation requirement is considered partially fulfilled.

MT members mentioned they would like to have a rather flexible model, so that from time to time it can be altered, as in adding a KPI to a certain category or removing one. Since instructions are provided in case this is needed, and construction of the dashboard was made taking that into account, the requirement for flexibility is entirely fulfilled.

Lastly, data accuracy is always a requirement, no matter what company or what industry it is in. Best decisions are made when data is accurate and when decision makers know what is actually going on and have the most up to date data. All information links were made, to extract data from the business intelligence platform, which provides the most up to date information. Yet, there is no guarantee that the information made available is accurate. This is a recurring problem at VDL ETG, especially to do with production data. It is easy for someone to forget to fill in data regarding the simplest process and so for all the above reasons, the requirement for data accuracy is considered partially fulfilled.

4.4.2. General Director and MT Members' Feedback

Once the dashboard's structure was entirely ready, working properly and all available links were established, a follow-up meeting took place with some MT members and the general director of VDL ETG. The main purpose of the meeting was to present the dashboard and collect all possible feedback from them.

Most comments regarding the dashboard were positive. The fact that it groups KPIs into categories and hierarchically into strategic, tactical and operational levels presents a big advantage. This provides a prioritizing system for the KPIs, it is clear where the focus should be, avoiding wrong resource allocation. The dashboard's main view is visually strong, where one can immediately identify the status of performance in each category.

The historical versus current data feature was highly appreciated, since it allows clear comparisons to be made. Furthermore, it was mentioned that a view into the future or trends would be interesting to have. MT members and the general director believe that one of the strongest aspect of the dashboard is the KPI library. Providing clear definitions to KPIs and making that information available will avoid all the miss understandings caused by the same named KPIs with different meanings.

The fact that this dashboard presents a very high level overview, key stakeholders believe that using it on a monthly basis would be unnecessary. Utilizing such model for their bi-annual meetings should make more sense, since they consider the dashboard as having a "mirror" function. It is a clear view of the as-is situation of VDL ETG. Having this dashboard as the first point of contact of data in these meetings would then lead the key stakeholders to the correct direction, enabling them to identify what areas should receive bigger attention.

The category division is also appreciated by the fact that it can serve as milestones. Through the bi-annual meetings, the dashboard can be used to see how performance levels are and the focus for the following six months could be to bring a specific category to the green level. Once this was successfully achieved, focus shifts to another category that is not yet green. All actions during the six months must take into account that increasing performance of the focusing category will not compromise the categories which were already at the green performance level.

MT members assigned an engineer that is specialized in excel and macros to exchange all the know-how of the model regarding all the codes. Even though all information is available in case users would like to add/remove a KPI to a category, key stakeholders advised for this meeting to take place.

Discussion about the future owner of the dashboard was carried out. The person responsible for it is, of course, the general director, whereas agreement towards the owner of the model's maintenance is obtained for the TQM manager.

Given all the above, the overall feedback was positive and the model was well accepted. There are high chances that once all data is made available, implementation will move forward in the bi-annual meetings.

4.4.3. Refining

First step for perfection is to make all data available and create the external links to it. This will provide the entire picture of performance with the highest accuracy possible. Once this is completed, the next refining action should be to implement the other KPIs considered "must haves" but were not implemented since there were other priorities. As mentioned before, SC has its dynamic characteristic so this model must be as dynamic as possible. For this to happen, on a yearly basis, KPIs should be revised to see if they are still to be in the high level overview or not. Possibly, over time, KPIs will be substituted by others, but this needs to be taken into consideration towards the dashboard so all information remains up to date.

5. Conclusions

This research addressed internal SCPMMSs for the case company. It provides VDL ETG with the best approach to the design for implementation of internal SCPMeS that drives value maximization for the customer at the lowest possible cost. It is made clear that SC strategies are directly linked to SCP, subsequently, taken into account the context of this research, the SCPMS framework was developed. Since it is highly acknowledged that management cannot exist without measurement, there was a clear need for a SCPMeS. Three frameworks are analyzed, coming to the conclusion that the best fit is the SMART pyramid.

The AS-IS situation was developed to come up with the KPIs in use at each department. Then the TO-BE scenario, where the ideal KPIs for VDL ETG (theoretically and also in terms of opinions derived by the stakeholders) are identified, was developed After comparing the AS-IS with the TO-BE situation, the missing KPIs are identified as "must haves". Due

to the time frame of this research, the top priority KPIs to implement (hence gaps to be closed) were identified based on empty categories within the performance pyramid. Three KPIs are implemented as an attempt to complete the pyramid and for all its categories to contain at least one KPI. Once this is achieved, the final SCPMeS is derived (for the time being).

Given the time span of the research, the design for implementation provided refers only to the internal SCPMeS. RADAR logic was used to complete this design where in the first step, all the requirements from MT members were made known, giving enough insight to develop a personalized approach to the design for implementation. The approach is the second step where the aim was to make the reader aware of how the approach developed aimed to fulfill all requirements presented by the MT members. It was made known that the deliverable is a communication tool in the form of a high level KPI dashboard that facilitates users to make better decisions by gaining access to an integral overview of how the case company is performing and what really needs to be improved or receive a bigger focus. The SCPMeS is the core element of the dashboard where all categories change color based on their performance level.

Step three of the RADAR logic is “deploy” and it represents the approach being carried out. The KPI dashboard structure is explained and all the 10 construction steps are identified. To complete the design for implementation, an assessment and review was made towards the deliverable to accomplish the last step of the RARAD logic. This segment analyzes if all the requirements presented are fulfilled by the deliverable or not. Recommendations to fulfill all the unfulfilled requirements are developed in the chapter conclusions. Furthermore, feedback meetings were taken place with the MT members and the general director and all the input was made known here. Positive reactions were identified with the strong possibility of a real implementation in the bi-annual MT meetings with the general director.

All of the information up to this point represents the conclusions drawn from this research. It is strongly believed by the researcher that a vigorous insight regarding how to successfully design for implementation a SCPMeS at VDL ETG driving overall customer value maximization at the lowest possible cost was provided.

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