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Dataset Management Quality Indicators for Start of Production Calibration Projects

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Abstract

The topic of this master thesis is the definition of key performance indicators for start of production calibration projects regarding dataset management quality.

The Goal Question Metric (GQM) approach and the derived GQM+Strategies approach are used to define a quality model for the dataset management in vehicle calibration. As proposed by GQM+Strategies, the business goals are explicated to enable structured measurements in alignment with the business goals.

After defining the measurements, a software prototype is built which enables measurements from the AVL CRETA database. AVL CRETA is a specific type of software for dataset management and market leader in the field. The implemented prototype is called AVL CRETA Quality Dashboard and is responsible for the technical implementation to take measurements for at least three KPIs.

On the basis of the data and the defined key performance indicators, a reporting system is set up to enable fast and efficient measurement iterations.

Kurzfassung

Diese Master Arbeit beschäftigt sich mit der Definition von Key Performance Indicators für „Start of Production“-Kalibrierungsprojekte bezogen auf Datensatzmanagementqualität.

Der Goal Question Metric (GQM)-Ansatz und der davon abgeleitete GQM+Strategies-Ansatz werden adaptiert, um ein Qualitätsmodell für das Datensatzmanagement in der Fahrzeugkalibrierung zu definieren. Wie im GQM+Strategies-Ansatz vorgeschlagen, werden die Unternehmensziele explizit dargestellt, um eine zielgerichtete Erfassung der Messdaten zu ermöglichen.

Nach der Definition der nötigen Metriken wird ein Software-Prototyp entwickelt, um die nötigen Informationen aus der AVL CRETA Datenbank zu extrahieren und zu verdichten. AVL CRETA ist eine Software der AVL List GmbH und wurde speziell für das Datensatzmanagement in der Fahrzeugkalibrierung entworfen. Der entwickelte Prototyp wird AVL CRETA Quality Dashboard genannt und umfasst die technische Implementierung der Messdatenerfassung für zumindest drei KPIs.

Auf Basis der erfassten Daten und der definierten KPIs wird ein rudimentäres Reporting-System aufgesetzt, um schnell und effizient GQM-Iterationen vornehmen zu können.

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1 Introduction

This chapter will outline the current situation and the scope of this thesis.

1.1 Initial Situation

The demand for robust and efficient dataset management increases steadily in start of production calibration projects. In this growing field, the AVL List GmbH wants to derive key performance indicators to establish a monitoring system for testing dataset management quality and to compare projects regarding dataset management quality.

1.2 Goals

The main goal of this thesis is to develop a quality model for calibration dataset management which enables a structured und unified way to evaluate calibration projects regarding dataset management. Key performance indicators shall be defined to give a quick overview of the performance of currently used processes and to show how well they are implemented in the different calibration departments.

This thesis is intended to be used as starting point or specification by the AVL CRETA development department in case that a decision is made to integrate the developed approach into the AVL CRETA dataset management tool.

Finally, a prototype shall be developed to test the approach in real customer projects.

1.3 Tasks

To achieve these goals, the following tasks will be covered in this thesis:

- Adaption of a suitable quality model to the field of vehicle calibration dataset management
- Application of the quality model including a well-structured representation and the definition of the required measurements

- Development of software tools to support measurements
- Derivation of key performance indicators
- Development of a front end solution for the management, the engineers and the AVL CRETA pilots to use and work with the results of the quality model

1.4 Area of Study

KPI-based measurement programmes are well established in software organisations to support decision finding, quality improvement and process improvement programmes (Antolić).

In this work, the Goal Question Metrics approach and partly the Goal Question Metrics + Strategies approach will be adopted to the field of vehicle calibration dataset management. Other researchers have already previously adapted the Goal Question Metrics approach to other fields than software development (Sarcia).

1.5 Approach

First the field of vehicle calibration and the environment (the company profile, existing processes, workflows etc.) is introduced. Then the usually occurring problems and issues in dataset management are analysed.

A quality model will be adapted to fit the needs of dataset management for start of production calibration projects.

Existing assets like processes, software tools and infrastructure of the AVL List GmbH shall be considered as much as possible to keep the effort and costs of introducing the new quality model low.

2 Theoretical foundation of the thesis

In this section, the necessary theoretical foundation will be discussed. Also, the environment, especially the AVL List GmbH and the existing assets in the company, will be described. Then, quality models and existing models with their fields of application will be outlined.

2.1 The AVL List GmbH

The AVL List GmbH was founded in 1948 with the target to build modern combustion engines based on the latest research. In the first years, the company achieved great successes in the field of diesel engine development.

In 1960, the company started with the production of engine measurement devices and emission-measuring devices.

The next great leap forward was around 1970, when AVL started to sell fully automated vehicle test beds.

In the following years, the company also became engaged in the racing sector.

Today, the AVL List GmbH is the largest independent supplier for the automotive industry with 45 affiliates worldwide and 8,050 employees. The fields of expertise include simulation and testing technology of powertrains for passenger cars including hybrid, combustion engines, transmission, electric drive, batteries and software and also trucks and large engines.

2.2 The Task of Vehicle Calibration

The number of different vehicle models on the market is steadily increasing (Fischer). Modern vehicle components like engine, transmission or the machine are used in different vehicles to decrease development costs. For the application and usage of such a component, a high degree of flexibility is needed to make it work correctly for different vehicle mass, tyre radius, chassis, load and various other properties of the target vehicle. Therefore, the controller unit is equipped with a software which enables the application engineer to adjust thousands of calibration parameters to achieve the required degree of flexibility.

To calibrate a component, an engineer establishes a connection with a calibration software like CANape (Vector Informatik GmbH) or INCA (ETAS High Tech Hardware Systems GmbH) to the control unit and changes the calibration parameters. Afterwards, he measures the vehicle behaviour using different manoeuvres and tries to find the best setting. Often, compromises must be found between driveability and e.g. fuel consumption.

The basic parts of a component like valves or hydraulic parts must be calibrated to work properly in the given component. This calibration is called base calibration. The base calibration is mostly done on a test bed and can already start when not all components are available in their final form. Meanwhile, the other components are simulated. After the base calibration, the components of the vehicle are calibrated in normal condition, which means a flat street and normal temperature. Then, different test trips are taken with the vehicle to check the behaviour of the calibrated parts under different environmental conditions (e.g. high altitude, hot and cold temperature).

There are different reasons why calibration is a very complex task (Dobes T.):

- Parameters influence each other
- Broad technical knowledge of the physical components and the given physical limitation is needed
- Vast knowledge of the control unit functions and implemented behaviour is needed
- Components influence each other
- Trade-offs must be made between different goals of the final product (e.g. sporty car versus comfortable car)
- Testing and validating the calibration values is demanding
- Different application engineers work on the same vehicle; therefore, the process of calibration must be coordinated and great communicational skills are required
- Calibration is the last step in a long chain of development activities; therefore, time delay before calibration can put on time pressure (e.g. a time delay in calibration usually results in a direct delay of start of production date, which can result in high costs)

Since there could be 50,000 or more calibration parameters for one single control unit which interfere with each other, a calibration process is applied to every single component to outline the different tasks of calibration and order them in a meaningful way.

Besides the technical challenges, there are different organisational challenges. Since most components are used in different vehicle variants, the components have to be calibrated and tested in each of the target vehicle variants. Often, a vehicle may be used in countries with different emission laws and different market requirements. Therefore, multiple engineers have to calibrate the different variants to meet the targeted start of production date. This leads to different forms of driveability because the subjective feeling of good driving behaviour varies from engineer to engineer. Still, the car manufacturer usually wants the vehicles in his portfolio to have the same driving experience (sometimes referred to as "DNA"). Also, each equal value over all vehicle variants results in a higher depth of testing because more variants used the same parameter values.

The communication effort increases the more variants exist and the more engineers have to align their work. If different engineers work on the same vehicle, the changes of calibration parameters by the engineers have to be aligned. The merging of calibration changes must be coordinated (e.g. more than one engineer proposes a different value for the same parameter).

The product of calibration activity is always a dataset for the calibrated component, valid only for the specific component with the specific vehicle set-up and for the target market (e.g. EU emission targets in comparison to Chinese emission targets).

2.3 Data – The Final Product

Before start of production (SOP), the final dataset must be delivered to the customer. Due to the calibration processes and the Dataset Management Workflow, it has to be ensured that all defined targets are met, and that the final dataset exhibits sufficient maturity and robustness.

For the release of the dataset, a release meeting is conducted which is attended by all responsible persons including the lead engineers, project manager, AVL CRETA pilot and the calibration engineers. During the release, Quality Gate review sheets are used to determine the current status in comparison to the targets defined.

If a decision for release is made, the results of the release meeting is summarised in a ‘recommendation for release letter' which is sent to the customer together with the dataset. This document has different names in the calibration departments (e.g. ‘Freigabeschein’[1], sheet of restrictions …), but the documents fulfil the same purpose.

During the release meeting, AVL CRETA is used to define the changes between the last and the current quality gate and to find out which labels were changed. There are different further usages like the comparison of different variants or the amount of changes for each parameter.

2.4 The Calibration Process

At the AVL List GmbH, there are different calibration processes for the different components. Each calibration process is split into work packages which contain different sub-work packages. The work packages stand for the combination of tasks to achieve the calibration of a high-level feature of the given component. The work package ‘Shift Strategy’ in the ‘Transmission Calibration Process’ covers all activities from the beginning to the end of the project which must be done to calibrate the shift scheduling of a modern automatic transmission. The sub-work packages split basic functionality and special functionality like sport modes or other special functions.

Each sub-work package consists of different parts which are defined in Table 1: Elements of a sub-work package.

[1] German word for term ‘release letter’

Table 1: Elements of a sub-work package

Element of sub-work package	**Purpose**
Inputs	Inputs define conditions which must be met and things that must be available to enable the calibration engineer to work on the sub-work package.
Tasks	Tasks determine what has to be done in the sub-work package.
Targets	Targets are a written description of the vehicle behaviour which has to be achieved to finish the sub-work package.
Outputs	Outputs define the generated reports, measurements or other things which have to be generated to finish the work package.
Target Score	The AVL CRETA score can be applied by the calibration engineer to all parameters which are assigned to the sub-work package if he fulfilled all defined targets and generated all defined outputs.

Each of these elements is defined for each Quality Gate. A Quality Gate determines a certain degree of maturity.

The label score is the synchronisation point between the calibration process and the dataset status in AVL CRETA. AVL CRETA can depict the work packages and sub-work packages and track the progress of the score.

In addition, the Quality Gate dates and the start of production date is saved in AVL CRETA. AVL CRETA can show the current state of the score.

2.5 The Dataset Management Workflow

The Dataset Management Workflow describes how calibration data is handled within the AVL List GmbH and is applied by the calibration departments. The description of Dataset Management Workflow is based on observations of the data handling in the calibration departments.

The execution of the Dataset Management Workflow within the AVL List GmbH is supported by AVL CRETA (Dobes T.). AVL CRETA is a Client-Server application specially developed for vehicle calibration. The key features of AVL CRETA are:

- central, secure storage for calibration data
- software and software update handling
- collaborative work flow with calibration data merge support
- report generation
- full history available
- support for vehicle variant handling
- user roles and responsibility management

Besides the listed features, AVL CRETA can assign different status to calibration data which was imported via calibration files. This status can be used to find problems or give additional information about the state of calibration change. The most important statuses used in this thesis are defined in Table 2: System status of parameters in AVL CRETA.

Table 2: System status of parameters in AVL CRETA

System Status	Description
OK	The import of this label occurred without errors and without permission violation.
LIMITS	The values imported for a parameter exceeded the allowed limit defined in the a2l file.

NO_PERM	The engineer imported parameters with changes which are not in his responsibility. This is a violation of defined permissions.
NO_PERM_SAVE	A change which represented a permission violation was marked as saved, which means that it is included in the next dataset. The save status can be set by the CRETA pilot or by the defined label owner.
DIM	The dimension of the parameter (e.g. map or curve) does not match the defined dimension in the hex file.

2.5.1 AVL CRETA

Within the AVL List GmbH, there are different calibration departments for the different components. Various habits in using AVL CRETA were established due to the different kinds of projects regarding size, type and customers' expectations concerning data management.

The responsibility for the dataset management is taken on by different roles in the different departments. In some departments, the project manager is responsible for the dataset management, and no other data manager or AVL CRETA pilot is defined. In other departments, there are AVL CRETA pilots who take on the intended role (compare Table 3: AVL CRETA User Roles). The responsibilities and authority of the pilots vary slightly in the individual departments.

Table 3: AVL CRETA User Roles

Administrator	Responsible for the infrastructure and correct handling of AVL CRETA. Can create new projects and users.
Calibration Pilot	Responsible for the dataset management within a project. Ensures that the Dataset Management Workflow is executed accordingly. Supports calibration engineers working with AVL CRETA, schedules and conducts label review meetings.
Calibration Engineer	Uploads the generated calibration data to AVL CRETA and sets comments and scores with respect to the calibration processes to these changes.

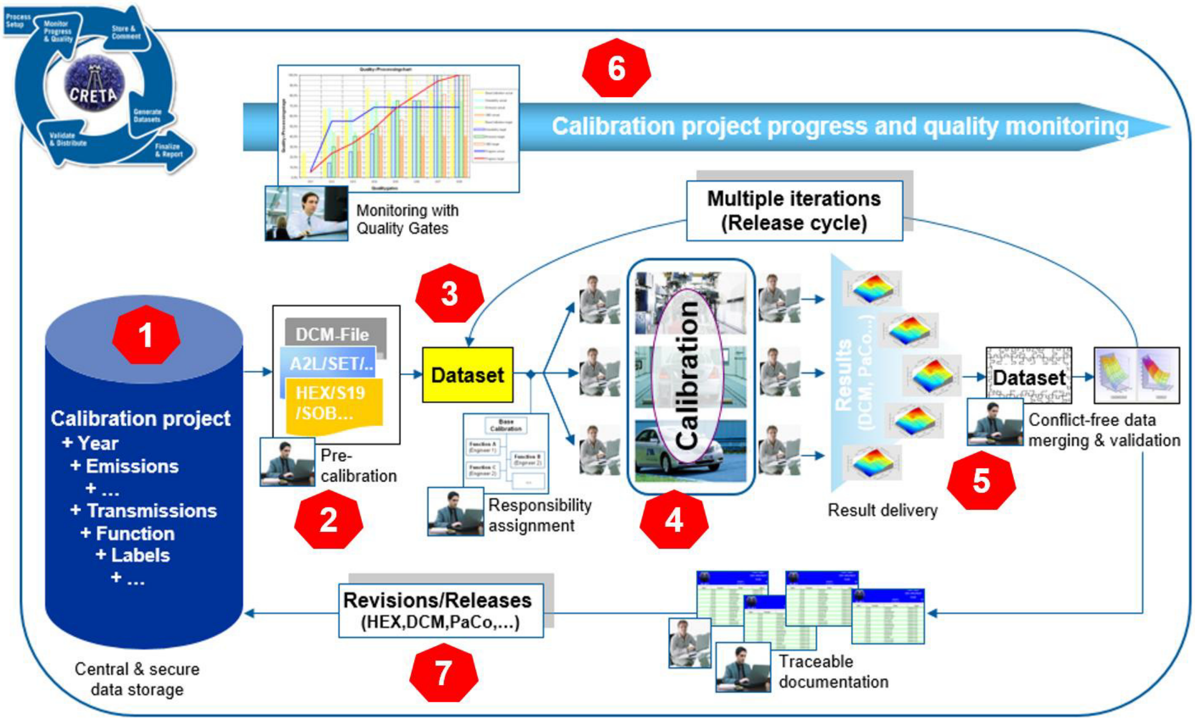

Figure 1: AVL CRETA Dataset Management Workflow

In Figure 1: AVL CRETA Dataset Management Workflow, the Dataset Management Workflow is shown. Certain steps of the workflow which can be measured are marked in red.

To evaluate the Dataset Management Workflow, the output of all steps, the quality criteria applicable to the steps and the possible impact an error in these steps can have on the project and the product are defined.

2.5.1.1 Calibration Attributes

Number one in Figure 1: AVL CRETA Dataset Management Workflow is the storage of calibration-relevant files and information. When software versions, datasets and variants are created and stored, the calibration pilot will insert attribute values in AVL CRETA.

These attributes are important to gain an overview of the vehicle's properties or variant which is calibrated. Attributes are for example fuel type, the number of gears, control unit and more specific information about the used hardware.

The knowledge of the environment in which certain calibration values operate enables reuse of calibration data, filtering and searching for specific vehicle properties. Furthermore, the attributes outline restrictions of the validity of the data for a certain vehicle.

2.5.1.2 Pre-calibration/Preparation

Before the calibration project starts, the software supplier (the AVL List GmbH in-house, the customers' software department or a third-party software supplier) delivers the initial software and dataset for the target component. This software is uploaded to AVL CRETA together with the delivered software documentation and calibration handbook. This step is depicted in number two in Figure 1: AVL CRETA Dataset Management Workflow.

The degree of maturity of the delivered software varies greatly from project to project. Sometimes, the initial dataset for a calibration project was already used in series of other vehicles, which means that the calibration values are meaningful. In other projects, the initial dataset is filled with dummy values (e.g. the maximum possible value or just zeros) or a coarse guess what values might work is made by the software department. Therefore, it is very important for the CRETA pilot to mention the source of the software (person/department) and the communicated history of the dataset (released notes and others).

2.5.1.3 Responsibility Assignment

Number three in Figure 1: AVL CRETA Dataset Management Workflow is the responsibility assignment and the assignment of parameters to work packages. This preparation is mandatory for the calibration task. The pilot assigns the existing parameters (called labels) to work packages. This is done with support from experienced calibration engineers or lead engineers. Afterwards, the work packages are assigned to calibration engineers. It is also possible that the assignment is done per parameter, per function or per sub-function. An example for a work package definition for the calibration of a hybrid control unit is shown in Figure 2: Work package definition for hybrid calibration. The first layer denotes the work packages and the second layer denotes the sub-work packages. All calibration parameters which are assigned to these work packages are in the responsibility of AVL. The work package is defined in the calibration process. There are other work package definitions for different components.

If only a part of the calibration is done by AVL, a label split between customer and AVL must be made. Customer labels are assigned to a particular work package entitled "customer". The work split between customer and AVL should be stated in the contract and should be agreed on by the customer. In the case of software updates when new labels can be introduced, the responsibility for the new labels has to be assigned.

A dummy project user is created for each customer and supplier in a project. Parameters which are in the responsibility of the customer are assigned to the according dummy user.

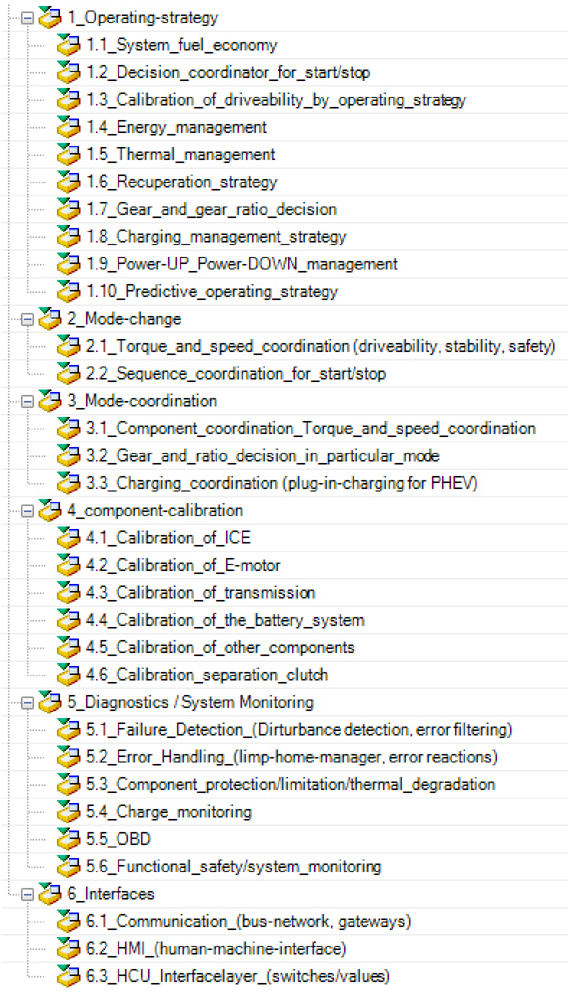

Figure 2: Work package definition for hybrid calibration (screenshot of AVL CRETA)

2.5.1.4 Calibration

In the recurring calibration phase, the calibration engineers download the current software and dataset from AVL CRETA and start working on their parameters. The calibration tasks and targets for each work package are obtained from the calibration processes.

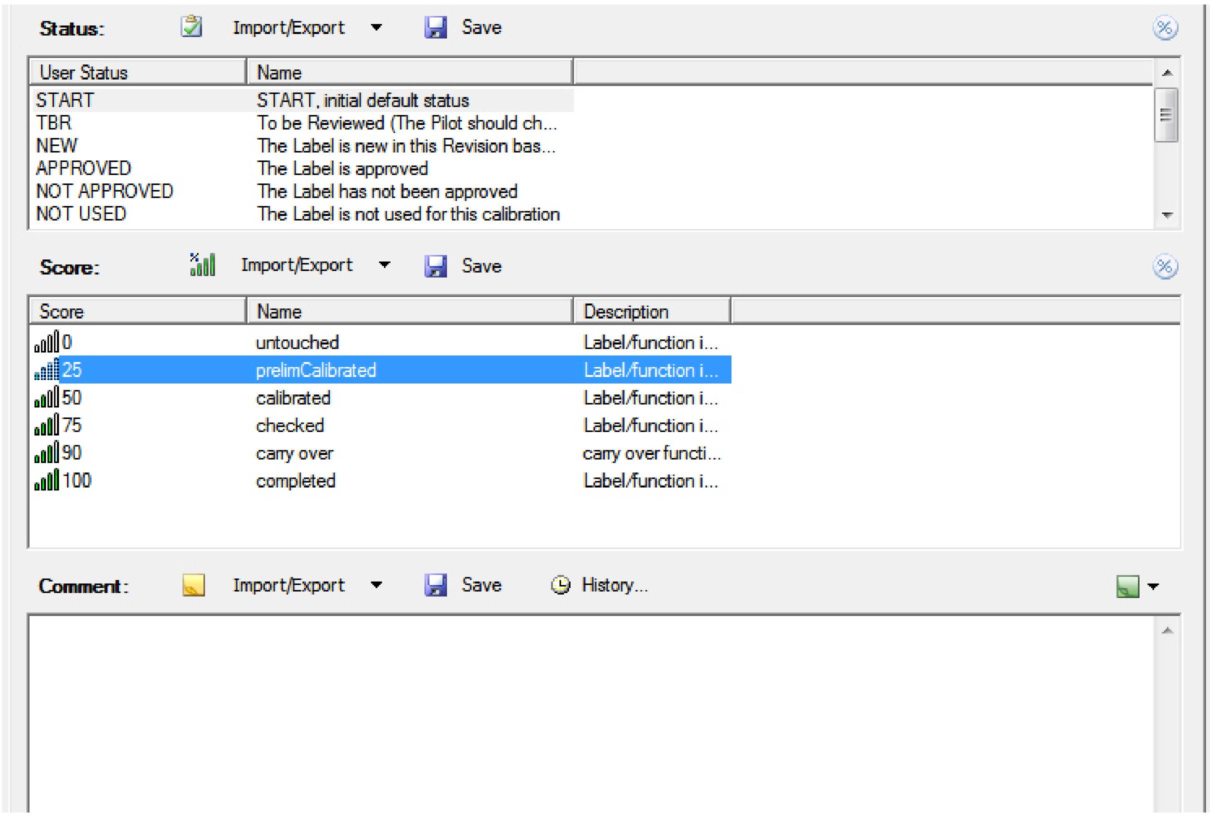

Figure 3: User Status, Score and Comment

At a defined time (e.g. daily) or before a dataset review meeting, the calibration engineers export calibration files from the calibration tools (Vector CANape or ETAS INCA) containing the changes. Those changes are then uploaded to the calibrated vehicle variants by the engineer. After the import, the engineer is able to set scores, comments and upload an attachment for each change.

2.5.1.5 Merging and validation of calibration results

The dataset review meetings usually take place weekly or biweekly. When the vehicle is calibrated on the test bed, many datasets are created per day. Then, even a daily dataset review meeting is possible and makes sense.

During the dataset review meeting, the AVL CRETA pilot meets with the calibration engineers and merges the calibration results. Hence, the changes contained in the uploaded calibration files are merged with the base dataset which was created in the previous dataset review meeting, and a new dataset is created.

During the merging, a check for conflicts is automatically done by AVL CRETA. A conflict means a situation when two calibration engineers changed the same parameter.

The engineer who violated the assigned responsibility is informed by AVL CRETA during the import of his calibration file. AVL CRETA assigns different statuses to the labels during the import. The owner of the parameter can then decide whether or not to accept the changes made by the other engineer. Ideally, this should be done before the dataset review meeting. If this is not possible, the conflicts will be shown again when the AVL CRETA pilot tries to merge the calibration files to generate a new dataset. Thus, the conflicts must be resolved during the meeting and the engineers are able to discuss which value is the best solution.

2.5.1.6 Project progress and quality monitoring

At the beginning of a calibration project, the quality gate dates are planned. Those dates are mostly determined by the SOP date, by vehicle availability and test trips alignment. The final quality gate dates are set with agreement of the customer.

For each quality gate, the calibration processes of the different vehicle components require a certain maturity and define certain targets and outputs which must be met to pass the quality gate. Since the calibration engineer determines the score for each label according to the calibration process, a quality report can be generated by AVL CRETA showing the current score, the minimum score (lowest score within one work package) and the target score for each quality gate. The project manager can use this report to get a quick overview of the current status.

Since there are thousands of calibrateable parameters in a control unit, it takes a considerable amount of effort to review the maturity of all labels in a work package. If a parameter has already a working value (e.g. set by the software developer as default value) and there is no need to change this value, it can happen that the score is not updated because the label has never been changed. There are also labels which are part of the software but are used in a function which is not activated for the target variant. Those labels could be considered to be finished (100% score) even if they will never be changed because the function is deactivated. The timing when those labels are updated to the target score of the current quality gate can distort the view of the real calibration progress since the score of the dataset may increase even if nothing has been changed.

Problems which may also arise are that the accuracy of the quality monitoring is determined by the calibration engineer's effort for setting the scores for each label according to the calibration process. The engineer for example can update the score with each of his changes, and so, the quality report is always highly accurate. If the engineer only updates the score prior to quality gates or only every three to four weeks, the quality report may not be representative.

2.5.1.7 Files managed by AVL CRETA

There are different files which must be managed by the dataset management software. The most important are listed in Table 4: Important file types for vehicle calibration.

Table 4: Important file types for vehicle calibration

File-Type	File ending	Purpose
Control Unit Software	.a2l	In the a2l-file, the calibration parameters are defined with their properties (e.g. units, axis, limits and read-only flag). The a2l-file is the minimum required file to connect a programme to the control unit. Without the a2l file, no calibration is possible.

		The a2l-file standard is defined by the ASAM (Association for Standardisation of Automation and Measuring Systems).
Dataset	.hex, .s19, …	The dataset contains a memory dump of the control unit and the software. It contains the whole address space of the device and therefore all calibration parameters. The dataset must fit to the a2l-file. It is used to flash a control unit.
Calibration File	.dcm, .par, .cdfx, …	The calibration file contains a subset or all parameters with values. Modern file types contain not only parameter names and values but different metadata information like description of the parameters or comments.
Attachments	*.*	Any file which is uploaded to a node in AVL CRETA. For calibration, the most important files are software and dataset release notes, documentation, recommendation for release letters, calibration guidelines, measurements and other files which could be used to document the work products.

2.5.2 Dataset Release

Prior to a quality gate, the team has to prepare the release of a new dataset. The release workflow is depicted in Figure 4: Quality Gate Release and shows which tasks have to be completed by the different parties.

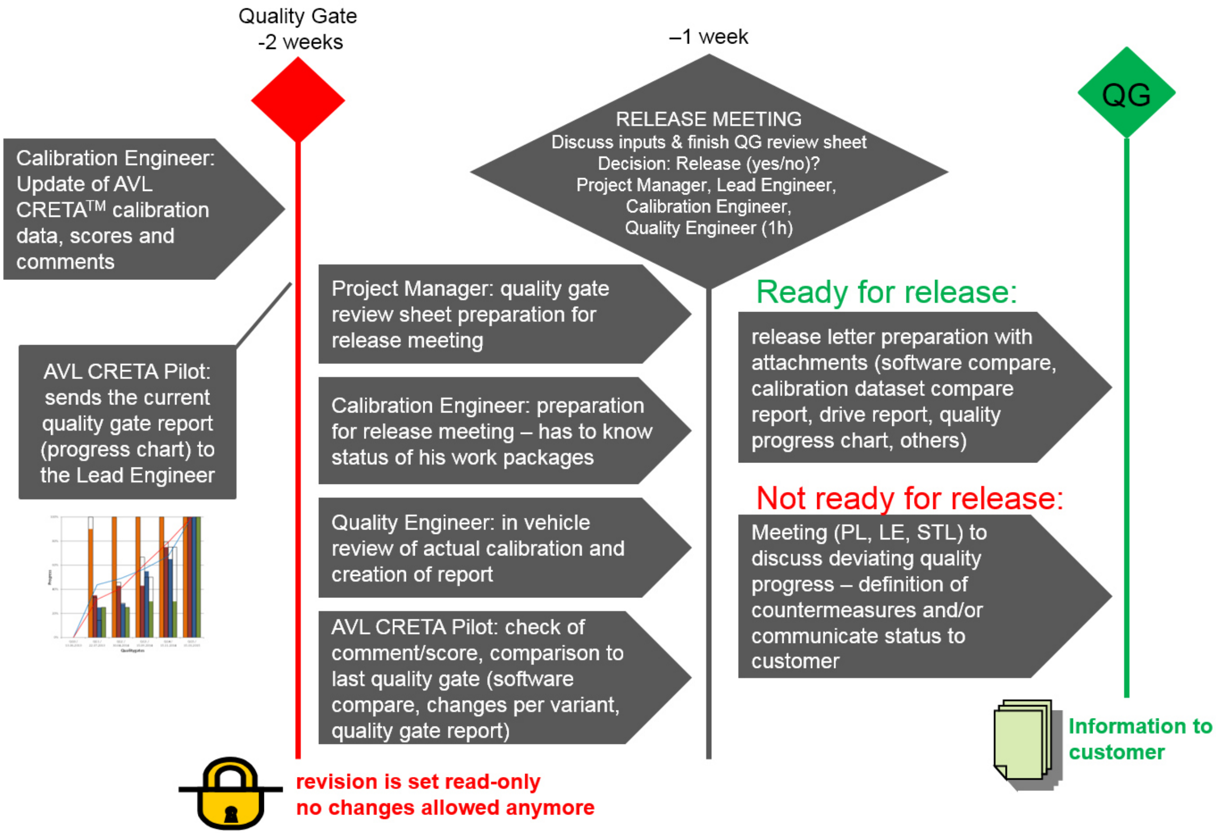

Figure 4: Quality Gate Release

The release of a dataset depends mostly on the data provided by AVL CRETA and therefore on the information which has been put into AVL CRETA by the calibration engineers. There are other instruments like quality gate review sheets or AVL Drive reports and AVL SPA (Shift Pattern Analysis) reports which can evaluate the current status of the vehicle without depending on AVL CRETA. Still, the main source of information for the dataset release is AVL CRETA.

As input for the release meeting which is conducted one week before the dataset release, the following documents are used:

- quality gate review sheets
- software compares
- dataset compares
- comments and scores
- reports to compare different variants of one project
- AVL Drive Report[2]

[2] AVL Drive is a software for objective drivability evaluation. It is well established over different vehicle vendors over the world.

- Draft of technical report

Since there are many parameters in a dataset, the lead engineers cannot check every single parameter. The Dataset Management Workflow with the ongoing label review meetings over the whole project runtime should ensure that the information in AVL CRETA is reliable. During the release meeting, each calibration engineer has to know and explain the current status of his work packages. All issues, deviations and current target achievements are discussed.

The output of the release meeting is a decision whether the dataset is ready for release or not. If the dataset is ready for release, a recommendation for release letter (or an equivalent document) is written which restricts the usage of the dataset to the tested range and is appropriate for the current maturity of the calibration. Also, an overview of the fulfilled work is given, and the changes or known limitations are explained by the calibration engineers. If the dataset is not ready for release, counter measures are defined, and the customer has to be informed if the delivery of a dataset is affected by the delay.

2.6 Issues current tools do not address

AVL CRETA is a vital tool for reliable dataset management. Still, there is room for improvement. The problems which will be addressed in this thesis are outlined in the following paragraphs.

2.6.1 Overview and Focus of Work

In larger projects with many vehicle variants and many datasets it is hard for the AVL CRETA pilot to get an overview and find out where problems occurred. He only sees the status of a dataset if he manually selects the dataset. For projects with many datasets, this can be time-consuming. With the quality dashboard, it should be easier for the pilot to quickly get to know which datasets or problems need his attention.

2.6.2 Timing schedule, planning and progress tracking

Since calibration is the last task in vehicle development before the start of production, the timing is very important. A deviation from the plan can lead to very high costs. Also, earlier deviations in development or late software updates may limit the available time for the calibration departments.

If no parameters have been changed for more than one week, this is usually an indication for a serious problem. Either there is no functional vehicle available for calibration or another blocking event occurred.

If the calibration engineer has not uploaded his changes for more than one week, this is an unwanted behaviour because of different reasons:

- Colleagues may be calibrating using the latest dataset available in AVL CRETA and may not work with the most current data
- The calibration notebook of the engineer might get damaged or destroyed and the data could be lost
- The current progress is not visible for the project manager or other parties who review the calibration effort in AVL CRETA

2.6.3 Completeness of Calibration

Another topic is the coverage of calibration. Usually, there are different types of parameters regarding how often they are changed. Some parameters which reflect physical properties of the vehicle like gear ratios or tyre radii can be fixed during the whole project after having set them initially.

Other parameters which are special features or software functions which are not part of the calibrated vehicle variant may be deactivated, and therefore, the affected parameters are not changed at all in the project. All remaining parameters should be calibrated at least once during the project. Getting an overview of the current calibration coverage is interesting to view the progress and to avoid missing the calibration of parameters.

It is possible that the initial value set by the software department is already a viable choice and is not changed anymore by the calibration engineers. Still, the calibration engineer has to look into all values to make sure they are sufficient.

2.6.4 Consideration of Software Changes

If a software change occurs, the changes between the software versions can be outlined by the software compare report which can be generated via AVL CRETA. Properties of a calibration parameter which may change are:

- the unit (e.g. km/h to mph)
- the dimension (supporting points are added or removed)
- the type (e.g. curve to map)
- the axis
- the function version

If the unit changes, the same values get a different meaning. If the dimension of maps or curves changes, former calibration values may not be integrated using the new software version as, e.g.

in case of a map, the new map is either smaller or larger than before. The same is also applicable to type changes. If the axis is changed, the values must be changed to preserve the same vehicle behaviour.

If the function version is increased but the other properties of a label are unchanged, which means using the same parameter values, the function may implement other routines, algorithms, or other behaviours. The calibration engineer has to be aware of the fact that the same value which was previously used for this label may now result in a different behaviour and the updated software documentation has to be reviewed.

A software update can invalidate previously valid calibration. Therefore, if the calibration is not updated accordingly to the software changes, arbitrary severe problems may arise. For projects with many variants and many parameters with changed properties after a software update, it is usually a lot of work to track whether the software changes resulted in updated values in the calibration datasets.

2.6.5 Quality and Frequency of Score Updates

In SOP projects, the calibration engineer should ideally update the scores of parameters with each change. If he does not find the time to do this or only updates the scores before a quality gate, the set score may not be reliable. It is advisable to question such scores. If the update happens seldom, the average score over time has a stepwise pattern as shown in Figure 5: Score increased continuously versus stepwise score increase.

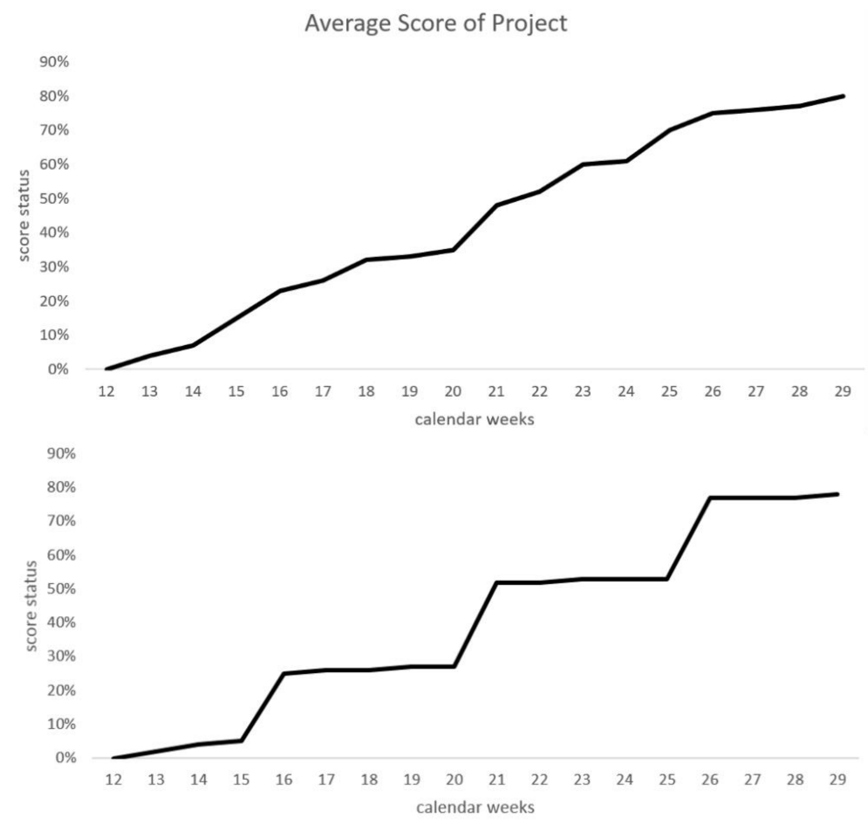

Figure 5: Score increased continuously versus stepwise score increase

In the reverse case if the score is updated frequently, the increase of average parameter score is more continuous. Since the calibration engineer should update the scores after each change, the continuously increasing pattern is expected to be more reliable and accurate than the stepwise increasing pattern.

2.6.6 Ownership of Parameters

AVL CRETA provides the possibility to assign an owner and a deputy for each calibration parameter. If an assigned responsibility is violated by a calibration engineer (e.g. via changing the values of another engineers parameters), this is shown in AVL CRETA.

Since the number of parameters may change (new parameters may be introduced and others may be removed from the software), the responsibility assignment must be updated accordingly. If no person is assigned as owner, the AVL CRETA pilot should be informed about this.

It may also occur that two people need the same parameter to finish their tasks and have different requirements or the responsibility assignment is not optimal (e.g. one engineer has to calibrate a feature of the component while some vital parameters for this feature are not part of his responsibility). Then, permission violations may occur when one engineer changes the label of another engineer. It should be made visible whether or not such permission violations occur multiple times for one label. If this is the case, it might be indicated to change the ownership of this label. In (Sarma), the lack of most configuration management systems regarding the awareness of what other parties are doing in a collaborative workspace is mentioned.

2.6.7 Changes of Critical Labels

There are parameters in every type of software which have a high influence on safety, emission or durability. And there are parameters which influence other functions which are typically calibrated later on in the project. Such parameters may be marked as VIP parameters to highlight that a change of such a label may have a great influence. Either those important topics are influenced or the schedule may not be met because the change of this parameter makes recalibration of other functions mandatory.

2.6.8 Summary

If the Dataset Management Workflow depicted in Figure 1: AVL CRETA Dataset Management Workflow is applied and all steps of the workflow are executed in decent quality, errors should be prevented and an overview of the calibration progress is always available.

The current situation in the AVL List GmbH's calibration departments is that the process capability regarding the Dataset Management Workflow is developed differently. AVL CRETA was introduced per department, and in each department, slightly the roles and responsibilities in dataset management were interpreted differently. E.g. in one department, the dataset management responsibility is a task of the project manager, while in other departments the role of an AVL CRETA pilot or calibration pilot is specially defined. The responsibilities of these roles also differ slightly. In most departments, the AVL CRETA pilot has no technical responsibility for the calibration values, while the differently defined role of a calibration pilot has technical responsibility besides the organisational responsibilities.

In the subsequent chapters, the viewpoint of AVL CRETA user roles as defined in Table 3: AVL CRETA User Roles will be used. Hence, all tasks which require a user to have pilot status within a project in AVL CRETA are referred to as pilot tasks. So, if in one department these tasks are completed by a project manager, the project manager is also a pilot from an AVL CRETA point of view.

For the execution of the Dataset Management Workflow, the result which is visible in AVL CRETA counts. It is evaluated whether the product of the Dataset Management Workflow is visible in AVL CRETA and not who completed the tasks. If work items or issues for a user are derived, the creator of the issue in AVL CRETA (for example, the person who imported a software or who uploaded a calibration file) will become the owner of the issue in AVL CRETA. For issues regarding pilots, the issue is assigned to all pilots of an AVL CRETA project if there is more than one pilot assigned to a project.

2.7 Selection of an Approach

After a short review of other approaches the Goal Question Metric approach was selected to develop a quality model for dataset management quality. Dataset management has many aspects in common with software development. For examples see the following listing.

- Version management is required
- Changes must be tracked and must be traceable
- Quality of the work products is not directly measureable (produced source code or calibration values alone cannot be directly used to measure quality)
- Multiple persons are working on the same artefacts (classes in software development, functions or work packages in vehicle calibration)
- The work products must be merged and conflicts must be solved

Since the GQM approach has its roots in the software industry and it was already shown that it can be applied successfully to the problems outlined above this approach was selected. (Basil)

2.8 Goal Question Metric

The issues outlined in 2.6 Issues current tools do not address will be addressed in this thesis. Since the progress in dataset management quality should be measured objectively and the measurements should be done in a structured way, it was decided to use Goal Question Metric (GQM).

Goal Question Metric is a well-tested approach for taking goal-oriented measurements in the field of software development introduced by (Basil) (Briand).

2.8.1 GQM Basics

Before the implementation of the GQM+Strategies grid, the strategies are partly used in the organisation in form of processes. In this case, these processes are the component calibration processes (e.g. transmission or engine calibration process) and the Dataset Management Workflow. The existing processes will be described in 3.1.1.1 Existing Assets.

Each organisation has goals and strategies which are defined by the organisational planning. Together with context factors and assumptions, the goals and strategies build the sub-model GQM+Strategies. In the left part of Figure 6, the organisational goals and strategies are shown.

The organisational goal refers to an anticipated state in the future. For each organisational goal, one or more related strategies are defined for achieving the goal. The identified goals will be described in 3.1.1.3 Definition of Goals.

Measurement goals (MG), questions (Q) and metrics (M) together with an interpretation model define the sub-model GQM graph. The GQM graph is the classic GQM approach. Measurements are taken to attain the organisational goals, and the organisational goals are measurable through the GQM graph. The GQM graph will be defined in 3.1.2.2 GQM Graph Details.

The approach taken in this chapter follows the GQM+Strategies approach described in (Trendowicz).

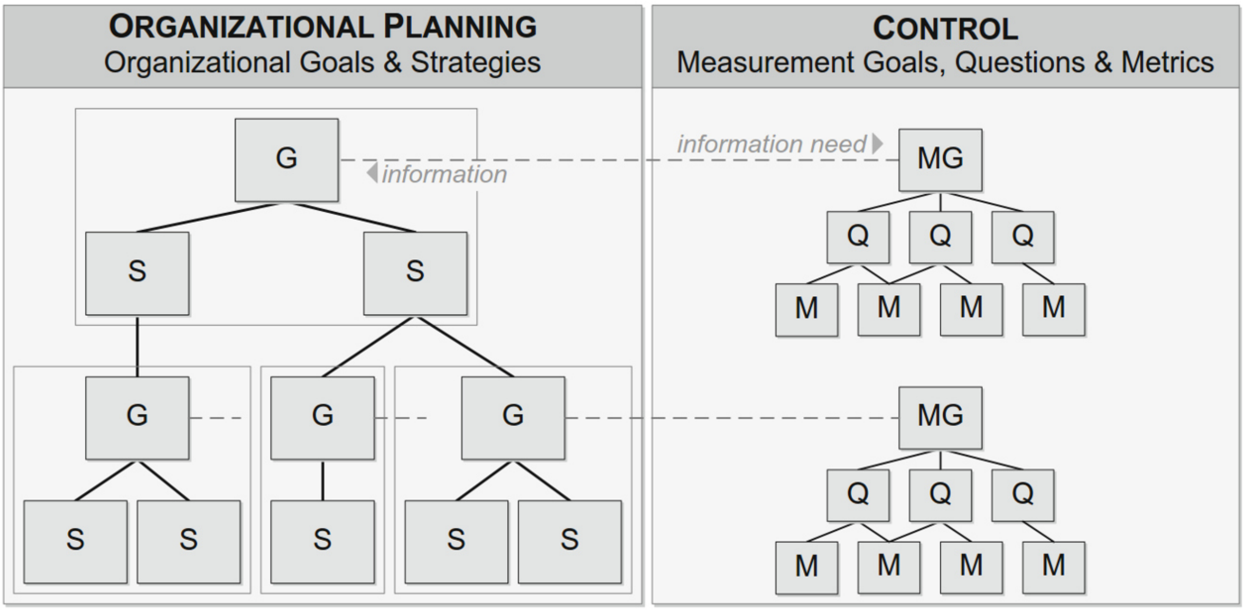

Figure 6: Relation between organisational goals (G) and strategies (S) and measurement goals (MG), questions (Q) and metrics (M)[3]

2.8.2 GQM+Strategies Process

The method GQM+Strategies embeds the GQM approach in a process which is shown in Figure 7: GQM+Strategies Process (pp. 14–16). The process steps are only a proposal. It depends on the company and how deeply the process should be implemented which steps and in which detail the steps are executed. In this work, the steps one to three will fully be executed, while step four will partly be executed. Step five and six will only be proposed for further work.

Subsection 2.8.2 GQM+Strategies Process is a summary of the subsection 2.3 in “Aligning organizations through measurement” by (Trendowicz).

[3] Image source: (Trendowicz) p. 11

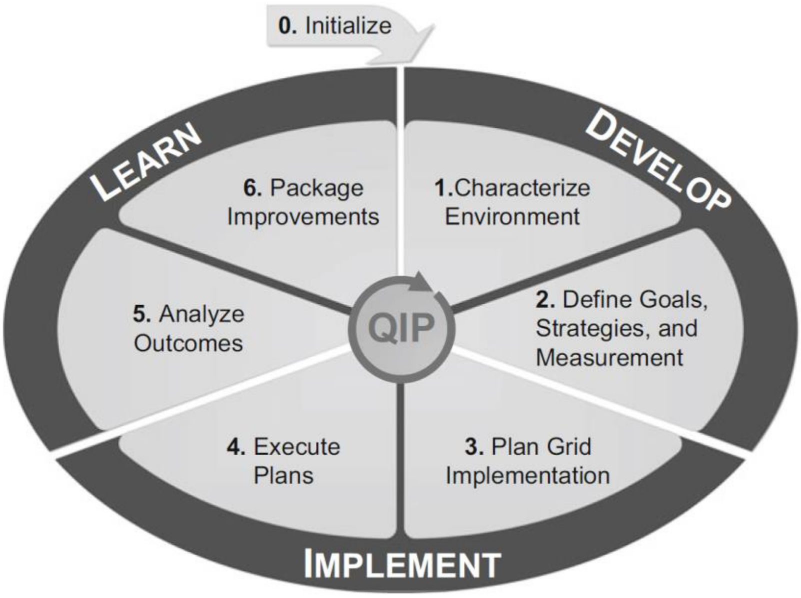

Figure 7: GQM+Strategies Process (Trendowicz) (pp. 14–16)

In Table 5. Definition of GQM+Strategies Process Steps, the single steps are defined in short. In Table 6: Execution of GQM+Strategies Process Steps, the execution of the process steps is described. Such quality improvement cycles are very popular in related work (Van Solingen).

Table 5. Definition of GQM+Strategies Process Steps

GQM+Strategies Process Phase	Definition and content of the process phase
1. Characterisation of Environment	The starting situation in the company, the environment and the current situation have to be characterised.
2. Definition of Goals, Strategies and Measurements	A model of the goals, strategies and measurement data must be developed. The model should be aligned with organisational strategies and goals.
3. Plan Grid Implementation	Plans for the execution of the measurements and the data which must be collected are specified.
4. Execution of Plans	The measurement takes place.

5. Analysis of Outcomes	Goal attainment and success or failure of strategies is checked. It is tried to identify the reason for failure or success.
6. Package Improvements	The generated knowledge from previous steps is used to improve the grid and change it where required. Assumptions and hypotheses are updated accordingly.

Table 6: Execution of GQM+Strategies Process Steps

GQM+Strategies Process Phase	Realisation in this work
Development (1. Characterisation of Environment; 2. Definition of Goals, Strategies and Measurements)	The first phase is fully executed during this thesis. The environment and existing assets are identified and characterised and the goals, strategies and measurements are defined.
Implementation (3. Plan of Grid Implementation, 4. Execution of Plans)	The prototype tool which is implemented during this thesis (the so-called CRETA Quality Dashboard) can be used to automatically gather relevant metrics for at least four measurement goals and, therefore, sets the foundation to establish a wider usage and efficient iteration of the GQM+Strategies Process.
Learn (5. Analysis of Outcomes, 6. Package Improvement)	Since the topic of this thesis is the definition of Key Performance Indicators and a prototype/mock-up of a Quality Dashboard, the steps five and six are topics for further work.

The importance of tool support to keep the cost of and effort concerning gathering measurements low is stated in (Deissenboeck).

2.9 Derivation of KPIs

After defining the organisational goals and the GQM graphs (see Figure 6), the gained knowledge of the connection between measured metrics and organisational goals are used to calculate the KPIs. Through the GQM graphs, the connection between the calculated KPIs and the organisational goals is demonstrated.

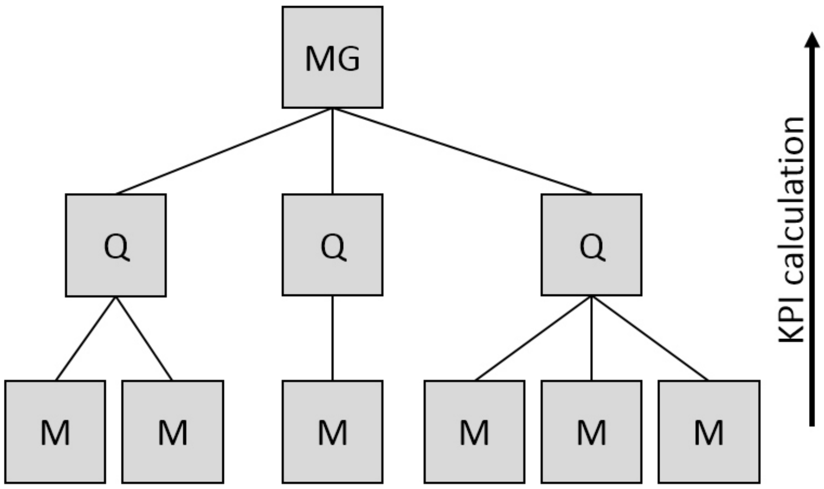

Figure 8: Calculation of KPIs using GQM graph definitions

3 Conceptual Framework for Dataset Management Quality

This chapter outlines a conceptual framework for dataset management quality. First, the adaption of Goal Question Metric to the field of vehicle calibration will be explained. Afterwards, the defined measurement graphs will be introduced followed by examples of how the GQM graphs can be translated into KPI values. Finally, examples for the reporting of analysis results will be given.

3.1 Applying GQM for Vehicle Calibration

This chapter gives an overview of the initial phases of GQM applied to the field of vehicle calibration and dataset management.

3.1.1 Initialisation of the GQM+Strategies Process

As a first step, the environment and context in which the measurements shall be taken had to be characterised. This was done in Chapter 2 Theoretical foundation of the thesis, which contained the description of the company, the environment and an introduction to the field of vehicle calibration.

3.1.1.1 Existing Assets

In the following paragraphs, the identified and already existing resources of the company will be described.

Component Calibration Process

A component calibration process characterises the calibration of a vehicle component. The process consists of one or more work packages with one or more sub-work packages. Each sub-work package has defined inputs, tasks, outputs, targets and a defined maturity score for each quality gate. There is one component calibration process defined for each major vehicle component (e.g. engine, transmission, hybrid control unit …). The calibration processes have a varying number of

Quality Gates depending on the component. The 'Transmission Calibration Process' for example has five Quality Gates (QG1–QG5).

The calibration processes will be explained in more detail in 2.4 The Calibration Process.

Dataset Management Workflow

The *Dataset Management Workflow* describes the intended calibration work flow. It outlines how AVL CRETA should be used as dataset management tool as well as the roles and tasks of the different project members including calibration engineers and AVL CRETA pilots. The Dataset Management Workflow was described in 2.5 The Dataset Management Workflow.

Definition of Purpose

From the viewpoint of this thesis the Dataset Management Workflow is a process, therefore the capability to execute this workflow is denoted as process capability. All AVL calibration departments use AVL CRETA together with the AVL *Dataset Management Workflow* as reference for the dataset management. Still, the process capability of the different organisational units is varying. Furthermore, the experience and acceptance of AVL CRETA in the calibration departments and by the individual engineers is different.

The Process Assessment Model of Automotive SPICE distinguishes between the following levels of capability (this is an extract of the definitions in (SIG) on p. 17):

Table 7: Automotive SPICE process capability levels

Level	**Definition**
Level 0: Incomplete Process	The process is not implemented or fails to meet its process purpose. At this level, there is little or no evidence of any systematic meeting of the process purpose.
Level 1: Performed Process	The implemented process meets its process purpose.

Level 2: Managed Process	The previously described Performed Process is now implemented in a managed fashion (planned, monitored and adjusted) and its work products are appropriately established, controlled and maintained.
Level 3: Established Process	The previously described Managed Process is implemented using a defined process that is capable of meeting its process outcomes
Level 4: Predictable Process	The previously described Established Process now operates within defined limits to achieve its process outcomes.
Level 5: Optimising Process	The previously described Predictable Process is continuously improved to achieve relevant current and projected business goals.

The process capability levels are defined in the ISO/IEC 15504-2. An overview and history of the development of SPICE is given in (Rout).

To find out which level of capability is accomplished by the different calibration departments, a standardised method of evaluation is needed. The focus will be on SOP projects because these are the most critical projects regarding time and quality.

Key Performance Indicators have to be defined to compare the performance in SOP projects between different departments and projects. The initial situation must be evaluated in the first iteration.

The current process capability level for dataset management may currently be at Level 2, Level 3 or Level 4. Since the calibration pilots are familiar with the process and control the execution of the process, the process is at least managed (Level 2). Sometimes, an entire department is familiar with the execution of the Dataset Management Workflow and expects that the process is executed according to its definition (label review meetings, release meetings etc.). In these departments, Level 3, Established Process, has already been achieved. A discussion about process quality and capability levels is provided by (Kneuper).

By implementing the GQM+Strategies process as depicted in Figure 7: GQM+Strategies Process (pp. 14–16), it should be possible to learn about the basic connection between the properties of the process and workflow products and the success in quality, cost and timing to achieve Level 4, Predictable Process. Later, if the loop is closed and iterations are done on a regular basis, this would lead to continuous improvement. The quality of the implementation of the Dataset Management Workflow will increase over all hierarchy levels (calibration engineer, CRETA pilot, and management). The engineer and the pilot will profit from the tasks generated by the AVL CRETA Quality Dashboard. The management will be able to monitor the dataset management quality in the SOP projects by reviewing the KPIs and reports.

Another effect of taking performance measurements is gaining a deeper understanding of how the Dataset Management Workflow performs and where improvements may be required (Sommerville).

3.1.1.2 Define of Scope

The affected organisational units are all calibration departments within the AVL List headquarters in Graz.

3.1.1.3 Definition of Goals

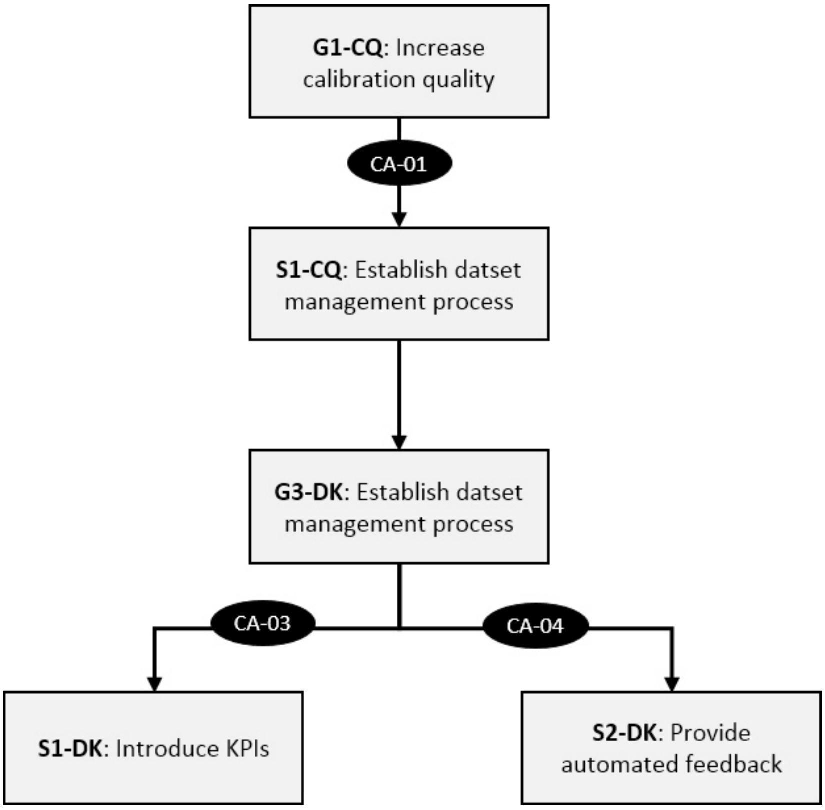

Figure 9: G1-CQ: Increase of calibration quality grid

In Figure 9: G1-CQ: Increase of calibration quality grid, the GQM+Strategies grid for the first goal *G1-CQ: Increase of overall calibration quality* is shown. In Table 8: G1-CQ: Increase calibration quality grid, an explanation of the elements is provided.

Items starting with 'G' denote goals, while items starting with 'S' signify strategies and items starting with 'CA' denote contexts and assumptions.

Table 8: G1-CQ: Increase calibration quality grid

G1-CQ	Increase of overall calibration quality
G3-DK	Establish the Dataset Management Workflow consistently and completely across the different calibration departments
S1-CQ	Establish the Dataset Management Workflow in a consistent and complete manner across the different calibration departments

S1-DK	Definition and introduction of KPIs regarding dataset management
S2-DK	Provide automated feedback to the calibration engineers concerning their conformance with the Dataset Management Workflow (constraint: software supported to keep the human resources bound by this task low)
CA-01	The Dataset Management Workflow enforces a good calibration practice, decreases the number of faults, increases productivity and reproducibility of satisfying calibration results
CA-03	To establish the Dataset Management Workflow, the monitoring and evaluation of the dataset management must be unified across different departments and different components which are calibrated
CA-04	If the individual calibration engineer gets feedback about his conformance with the Dataset Management Workflow, the capability of the departments to execute the workflow will rise

The goals and expectations in non-formal language are:

- *We want to make visible how well the Dataset Management Workflow is executed in (SOP) projects, evaluate the current quality of dataset management in the project and enable the comparison of projects by introducing KPIs. (G3-DK)*

- *We expect to increase the transparency in calibration, increase documentation coverage and a better monitoring of target achievement and quality. (S1-CQ, S1-DK)*

- *We want to give the calibration engineer and the AVL CRETA pilot a tool which enables them to find out where actions from their side are required and provide feedback about their usage of AVL CRETA. (S2-DK)*

- *Through the CRETA Quality Dashboard features and the possibility to provide automated, continuous feedback, we expect a more efficient work flow in calibration and a higher dataset quality. (S2-DK)*

3.1.2 GQM Graph Definition

The Goal Question Metric Graph shows the relationship between goals, questions and metric.

A measurement goal describes the information which must be attained to decide about the success of the defined organisational goals and strategies. For every measurement goal, a set of questions is derived. These questions need metrics to be answered. The metrics are either generated from collected data or are the collected data.

In (Trendowicz)[4] the following steps are outlined for the GQM Graph definition (direct citation):

a. *developing a set of well-defined measurement goals for the quantities of interest in the GQM+Strategies goal, e.g., customer satisfaction, on-time delivery, improved quality, schedule*
b. *generating questions (based upon models) that define those goals as completely as possible in a quantifiable way*
c. *specifying the metrics that need to be collected to answer those questions and to track process and product conformance to the goals*
d. *developing mechanisms for data collection*
e. *collecting, validating, and analysing the data in real time to provide feedback for corrective action*
f. *Analysing the data in a post-mortem fashion to assess conformance to the goals and make recommendations for future improvements.*

3.1.2.1 Explanation of Measurement Goals

In Table 9: Overview of defined GQM measurement goals, the specific goals are described in short. Afterwards, the GQM goal template is used to specify each goal in more detail with targets, viewpoint and context.

[4] Compare p. 38

Table 9: Overview of defined GQM measurement goals

Calibration Continuity (MG2-CC)	Measurement if continuous calibration activity is going on in the project. The number of changes and the time when changes are made should be evaluated. This may vary because different teams have different upload schedules for their changes. Helps check whether calibration results are stored in AVL CRETA.
Calibration Coverage (MG3-CCov)	Measure the coverage of changes with respect to the parameter responsibility of AVL. Requires that responsibility and the work split for all parameters is defined. Assumption which coverage is normal for different project types has to be made.
Responsibility Conformance (MG1-RC)	Measure whether the responsibility of parameters is defined, first between customer and AVL and then AVL internally (assignment of parameters to engineers). Measures whether the calibration changes are done in conformance with the defined responsibility.
Critical Changes (MG4-CritChg)	Measure whether critical labels are defined in the project. Check when and how often critical labels are changed.
Documentation Continuity (MG5-DC)	Measure whether value changes are documented in AVL CRETA. Measure if changes of meta-data like maturity/score are documented and check whether the chain of comments is free of interruptions.
Attachment Usage (MG6-AU)	Measure whether attachments are used to document software changes, store software release notes and whether value changes of labels with high maturity are commented by storing additional files in the attachments.
Meta-Data Usage (MG7-MU)	Measure whether meta-data is used to document the properties of variants, software versions, datasets and projects in AVL CRETA. Checks whether the required information for the quality gates is available for the variants (SOP date and quality gate dates).

Software Change Considered (MG8-SCC)	Measure how many software changes which can have an impact on the resulting product quality are reflected in calibration changes. Measure whether recalibration takes place where appropriate.
Score Continuity (MG9-SC)	Measure whether scores are updated regularly.
Process Conformance (MG10-PC)	Measure whether the configuration of the project supports the calibration process. For example: whether the parameters are assigned to work packages, whether a quality gate template was uploaded to AVL CRETA and whether the target scores are defined for all quality gates together with the quality gate dates. Checks whether the quality gate report can be generated and how regularly new datasets are generated.
Target Achievement (MG11-TA)	Measure whether the quality progress corresponds with the planned project schedule and the expected quality at the next quality gate date.

3.1.2.2 GQM Graph Details

This section explains the developed goal question metrics grids. The grids contain the measurement goal on the top level. On the second level, they show the related questions and the required metrics which should be measured on the third level.

After each grid, a short explanation of the grid items and definition of terms which are used in the grid is given.

3.1.2.3 MG Responsibility Conformance

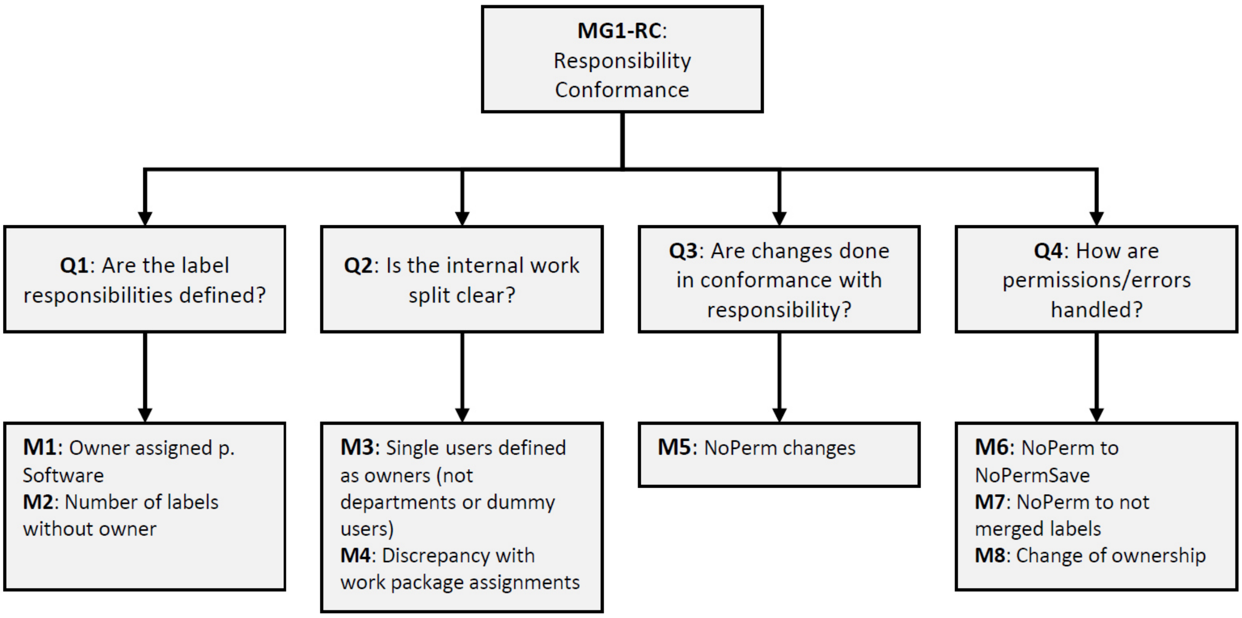

Figure 10: MG1-RC Responsibility Conformance

In Figure 10: MG1-RC Responsibility Conformance, the GQM Graph for the first measurement goal *Responsibility Conformance* is shown.

Question 1 refers to the label responsibility assignment in AVL CRETA. At the beginning of a project, after the first software was delivered from the customer, an owner has to be defined for each label. If labels do not have an owner, there is a risk that labels are not calibrated, or discussions about responsibility will start later on. This question targets the work divided up between customer and supplier. Therefore, dummy users and user groups are allowed to be owners.

Question 2 targets labels which are under the responsibility of AVL. The only allowed users are single users or dummy users. No user groups are allowed at this point. Since responsibility is not divisible, each label needs to be assigned to a person responsible. If a work package assignment already exists, it can be double-checked. Customer (dummy user) labels must be assigned to customer work packages, and AVL labels must be assigned to AVL work packages. If discrepancies are found, either the work package assignment or the ownership assignment is wrong. All discrepancies must be resolved.

Question 3 checks whether the changes done during project execution are in conformance with the defined label responsibilities. A NO_PERM status is assigned to a changed value by AVL CRETA if an engineer changes a label which is in another engineer's responsibility. If all changes are done in conformance with the defined responsibility, M5 should be zero. The only exceptions are changes sent by the customer which are uploaded to AVL CRETA by the CRETA pilot.

Question 4 targets the processing of NO_PERM changes. There are different possibilities. M6 refers to the changes which were accepted by the label owner and therefore received the status NO_PERM_SAVE. These labels are merged into the next revision. If no one accepts a NO_PERM change before the next merging, it will not be included in the next revision. In response to NO_PERM changes, the responsibility of a label may change when the project team decides that the ownership assignment is wrong. Those labels are described by M8.

Table 10: Measurement Goals: Responsibility Conformance

Analyse	The distribution of parameter responsibility between customer and AVL and AVL internal
To	Evaluate whether the parameters were assigned to persons responsible; identify errors in responsibility assignments; improve the time after project start until the responsibility is defined
With respect to	Work package assignment; contract and assigned ownership in AVL CRETA
From the point of view of	Calibration pilots
In the following context	Vehicle component calibration projects

3.1.2.4 MG Calibration Continuity

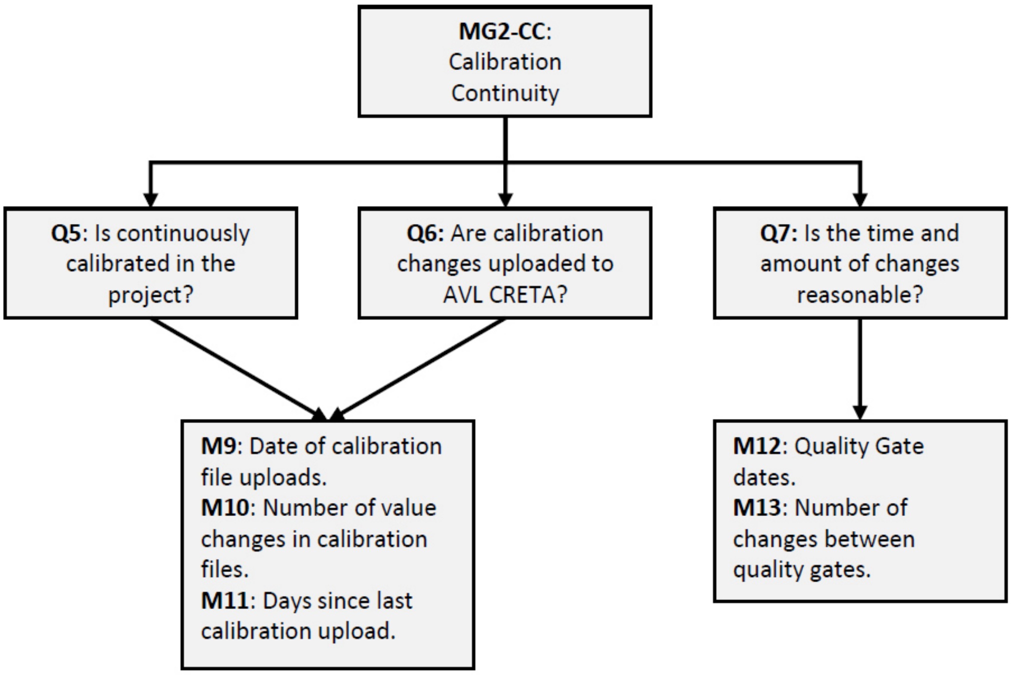

Figure 11: MG2-CC Calibration Continuity

In Figure 11: MG2-CC Calibration Continuity, the graph for the measurement goal *Calibration Continuity* is shown.

Question 5 evaluates whether new calibration data is generated continuously in the project. If M11 is high, there is either an issue blocking the progress in the project or, as evaluated in question 6, engineers did not upload their calibration results to AVL CRETA. In both cases, an action is required.

Question 7 evaluates whether the amount of changes is reasonable for the project phase. Later in the project, a higher degree of maturity is expected and should be reflected in less changes with smaller magnitude. To know the project phase, the quality gate dates must be clear. Since the Quality Gate dates are only defined for SOP-projects, M12 and M13 cannot be gathered for all projects. Alternatively, the number of changes over calendar weeks could be evaluated.

Table 11: Measurement Goal: Calibration Continuity

Analyse	The number of calibration changes
To	Evaluate whether the calibration is undisturbed and ongoing; evaluate whether the number of changes is reasonable; predict whether delays are probable
With respect to	The project phase, timing, project type, scheduling of label review meetings, test trip status, calibration vehicle status (unplanned delays)
From the point of view of	Calibration pilot, responsible managers
In the following context	Vehicle component calibration projects

3.1.2.5 MG Calibration Coverage

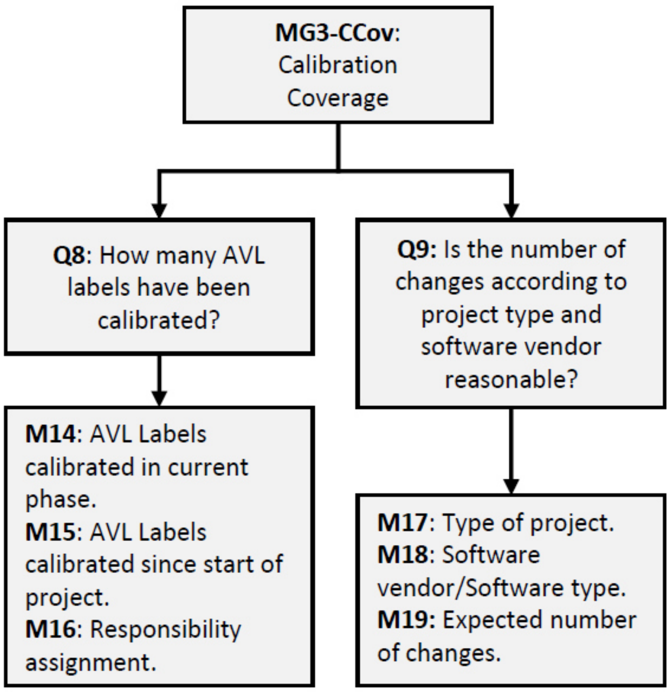

Figure 12: MG3-CCov: Calibration Coverage

In Figure 12: MG3-CCov: Calibration Coverage, the graph for the measurement goal *Calibration Coverage* is shown.

Question 8 evaluates how many different labels AVL is responsible for were calibrated. The numbers are collected for the single project phases if applicable and usable for the whole project. A phase is the time span between two quality gates as defined in the calibration processes. Question Q8 and Q9 can only be answered if the responsibility assignment was completed. The coverage for the expenses of the current project phase can only be calculated if the quality gate dates are defined.

Question 9 evaluates whether the number of different calibrated labels is in conformance with the expected number of calibrated labels for the given project type and software vendor in each project phase.

Table 12: Measurement Goal: Calibration Coverage

Analyse	The coverage of calibration changes
To	Learn about the typical calibration coverage of a successful and an unsuccessful project and predict whether the coverage is sufficient to gain a satisfying result
With respect to	Project type, timing, component type, expected calibration coverage
From the point of view of	Responsible managers
In the following context	Vehicle component calibration projects

3.1.2.6 MG Critical Changes

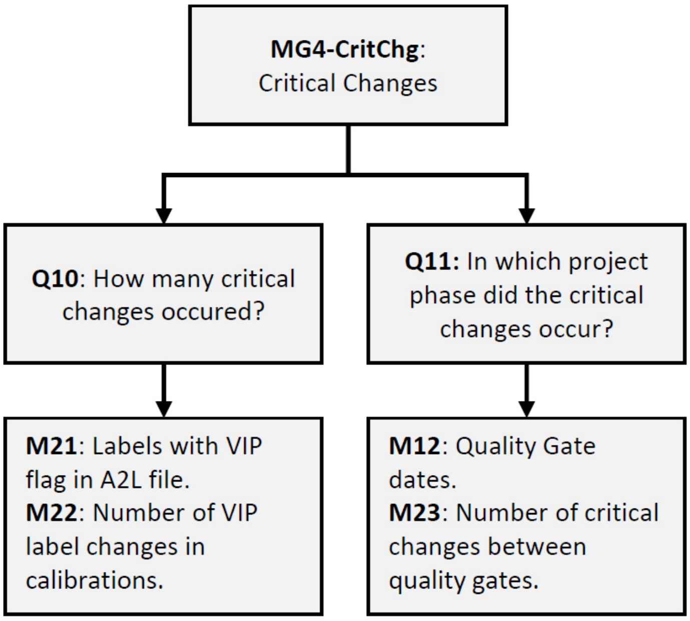

Figure 13: MG4-CritChg: Critical Changes

In Figure 13: MG4-CritChg: Critical Changes, the graph for the measurement *Critical Changes* is shown.

A label should be considered as critical if one of the following conditions is true:

- Changing the label makes changes of a multiple of other labels mandatory
- Changing the label makes changes of high complexity to other labels mandatory
- The change of this label has influence on the security of vehicle passengers
- Due to the logical sequence of calibration, changes regarding this label should only occur in a certain project phase (e.g. pedal map before shift map calibration)

Question 10 evaluates how many critical changes occurred. Since critical labels can result in recalibration of other labels, they should not be changed often. If they are critical labels because of their importance for passenger security, the changes have to be done very carefully.

Question 11 is important because changes of critical labels in later phases of the project can result in timing issues. If a critical label is changed too late in a project, it is possible that a quality gate or even the SOP date cannot be met.

To mark critical labels, the VIP-flag in the A2L file is used.

Table 13: Measurement Goal: Critical Changes

Analyse	The number and time when critical changes (changes of VIP labels) occur in a project, if VIP flags are set in AVL CRETA, and if critical labels are defined.
To	Learn when critical changes occur and which impact these changes have; improve the awareness about changes done to critical labels; reduce the number of changes of critical labels in later project phases; reduce recalibration effort
With respect to	Project type, timing, calibration phase
From the point of view of	Responsible managers, calibration pilots, calibration engineers
In the following context	Vehicle component calibration projects

3.1.2.7 MG Documentation Continuity

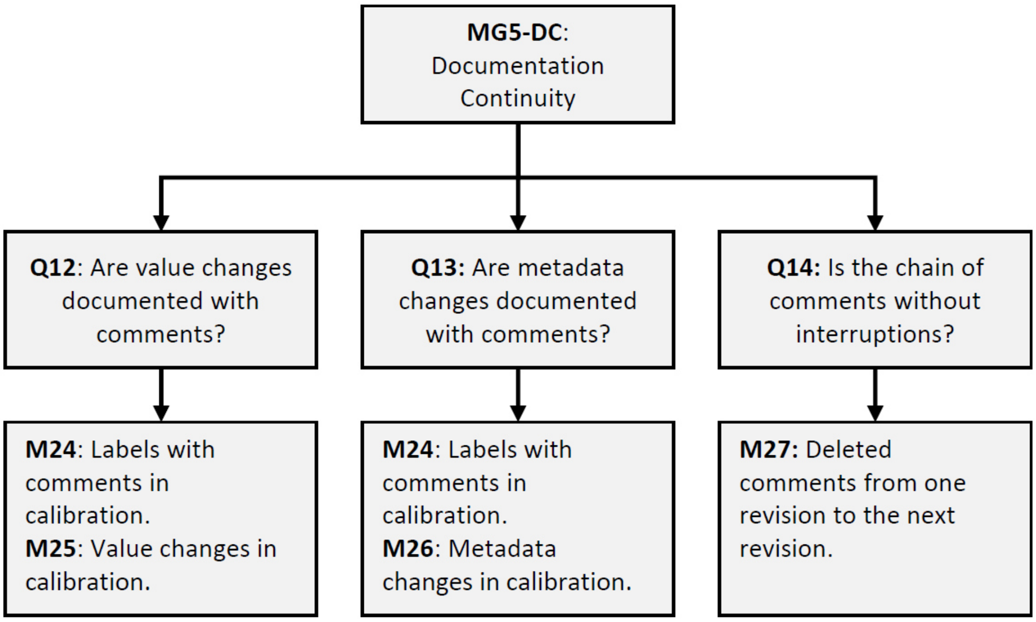

Figure 14: MG5-DC: Documentation Continuity

In Figure 14: MG5-DC: Documentation Continuity, the graph for the measurement goal *Documentation Continuity* is shown.

Question 12 targets the number of value changes which are documented using a comment in AVL CRETA. Each calibration change has a reason, and therefore, documenting the reason why the change occurred is important to understand the change later in the project. The documentation of a label in AVL CRETA contains a list of change comments. Hence, clear and descriptive comments avoid having to do work twice.

Question 13 targets the number of meta-data changes which are documented. For example: If a score is reduced (decreased maturity), the reason why this was done should be explained in a comment.

Question 14 checks whether the comments were transferred from one revision to the next. This should happen automatically during a merging but it is not enforced by AVL CRETA.

Table 14: Measurement Goal: Documentation Continuity

Analyse	The number of documented calibration changes
To	Evaluate the ratio of calibration changes which are documented; improve the number of changes which are documented
With respect to	Parameter maturity, project phase
From the point of view of	Calibration pilots, calibration engineers
In the following context	Vehicle component calibration projects

3.1.2.8 MG Attachment Usage

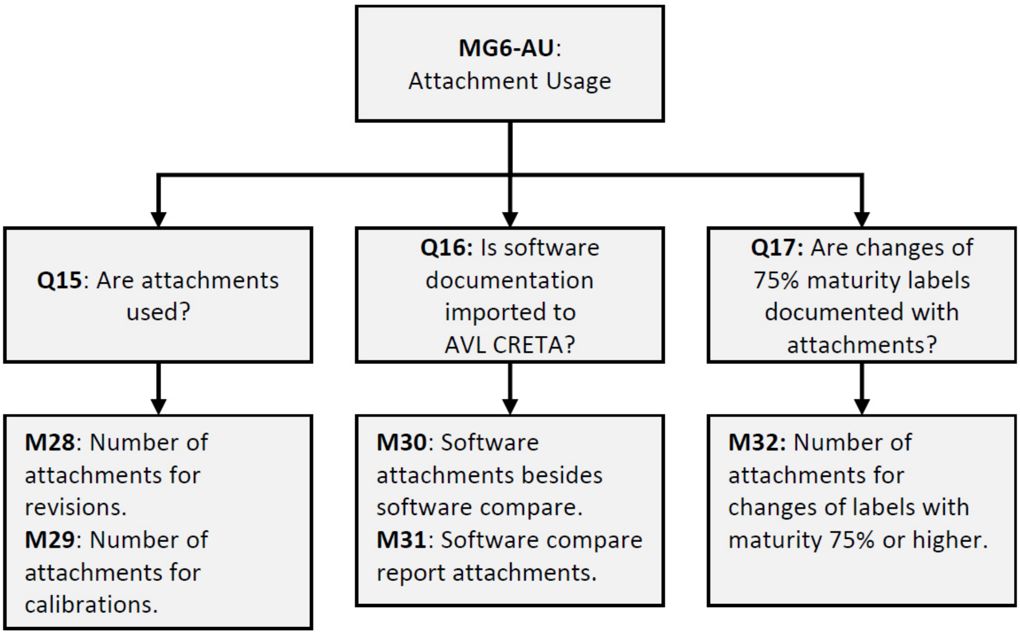

Figure 15: MG6-AU: Attachment Usage

In Figure 15: MG6-AU: Attachment Usage, the graph for the measurement goal *Attachment Usage* is shown.

Question 15 targets the attachments of revisions and calibrations. If there is a new dataset or calibration file sent by a supplier (or the customer) and if release notes for those are available, the latter should be attached to the revision. Calibrations can also have attachments like screenshots of measurements before and after the calibration change.

Question 16 targets the attachments of software versions. The software compare report is the bare minimum needed by the calibration engineer. The software compare report contains all information on removed, new and changed labels and what has changed from the last to the current software version. Since the A2L file only contains the description of the labels and not the behaviour of the software, software documentation is mandatory if labels were added or the functionality was changed.

Question 17 targets a new approach which requires a short presentation to be added to every change of a label after 75 percent maturity. The presentation should include the situation before the change, the information on what has been changed and the resulting situation after the change.

Table 15: Measurement Goal: Attachment Usage

Analyse	The usage of the attachment features of AVL CRETA
To	Evaluate whether software release notes, calibration guidelines, recommendation for release letters and other important documentation or documents related to calibration are uploaded to AVL CRETA; motivate the upload of files to AVL CRETA
With respect to	Node type, document type
From the point of view of	Calibration pilots, calibration engineers
In the following context	Vehicle component calibration projects

3.1.2.9 MG Metadata Usage

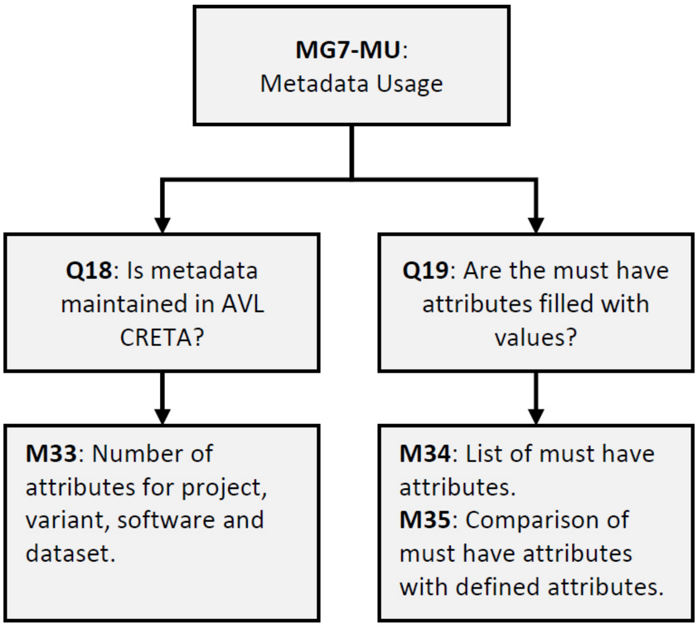

Figure 16: MG7-MU: Metadata Usage

In Figure 16: MG7-MU: Metadata Usage, the graph for the measurement goal *Metadata Usage* is shown.

Questions 18 and 19 target the attributes set for the different elements in AVL CRETA. There are basic attributes like the project number and project manager which must always be specified. Also, there are different attributes for the target emission classes and vehicle properties. Those attributes represent the environment in which the calibration data was generated (the status and composition of the vehicle components).

If the attributes are filled accurately and as completely as possible, the reuse of data is probable.

Table 16: Measurement Goal: Metadata Usage

Analyse	Number and type of metadata information provided
To	Evaluate whether metadata information is used; improve the volume of available hardware, legislation, maturity and other information in AVL CRETA; improve the reusability of data

With respect to	Component type, project type (prototype, SOP etc.)
From the point of view of	Calibration pilots, calibration engineers
In the following context	Vehicle component calibration projects

3.1.2.10 MG Software Changes Considered

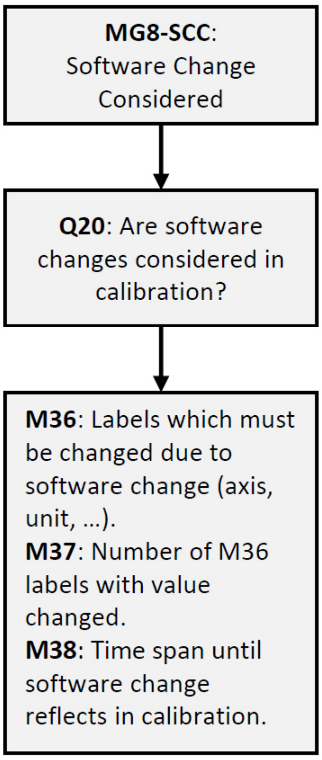

Figure 17: MG8-SCC: Software Changes Considered

In Figure 17: MG8-SCC: Software Changes Considered, the graph for the measurement goal *Software Change Considered* is shown.

Question 20 targets the influence of software changes on calibration. In most cases, software changes have an impact on calibration. Usually, new software is delivered together with a new dataset. The previous calibration results must be carried over to the new dataset. The labels affected by the software change cannot be transferred and must be recalibrated, or at least changed, to meet the new label properties (e.g. if the number of supporting points in a map changed).

The needed metric are the labels which must be changed due to the software update denoted by M36.

M37 describes the labels which already had a value change after the software change. Those labels are considered to take the software change into account.

M38 denotes the time span until the labels were updated. Updates should be done directly after the new software became available in AVL CRETA.

If software changes are not considered in the calibration, this could have a severe impact on quality, durability and safety.

Table 17: Software Change Considered

Analyse	Consideration of software changes in calibration changes
To	Evaluate whether software changes are reflected in calibration changes; ensure that no critical software changes are unnoticed; improve awareness of software changes and effects
With respect to	Software versions, software compare report in AVL CRETA, type of software change (dimension, limit, unit etc.)
From the point of view of	Calibration pilots, calibration engineers
In the following context	Vehicle component calibration projects

3.1.2.11 MG Score Continuity

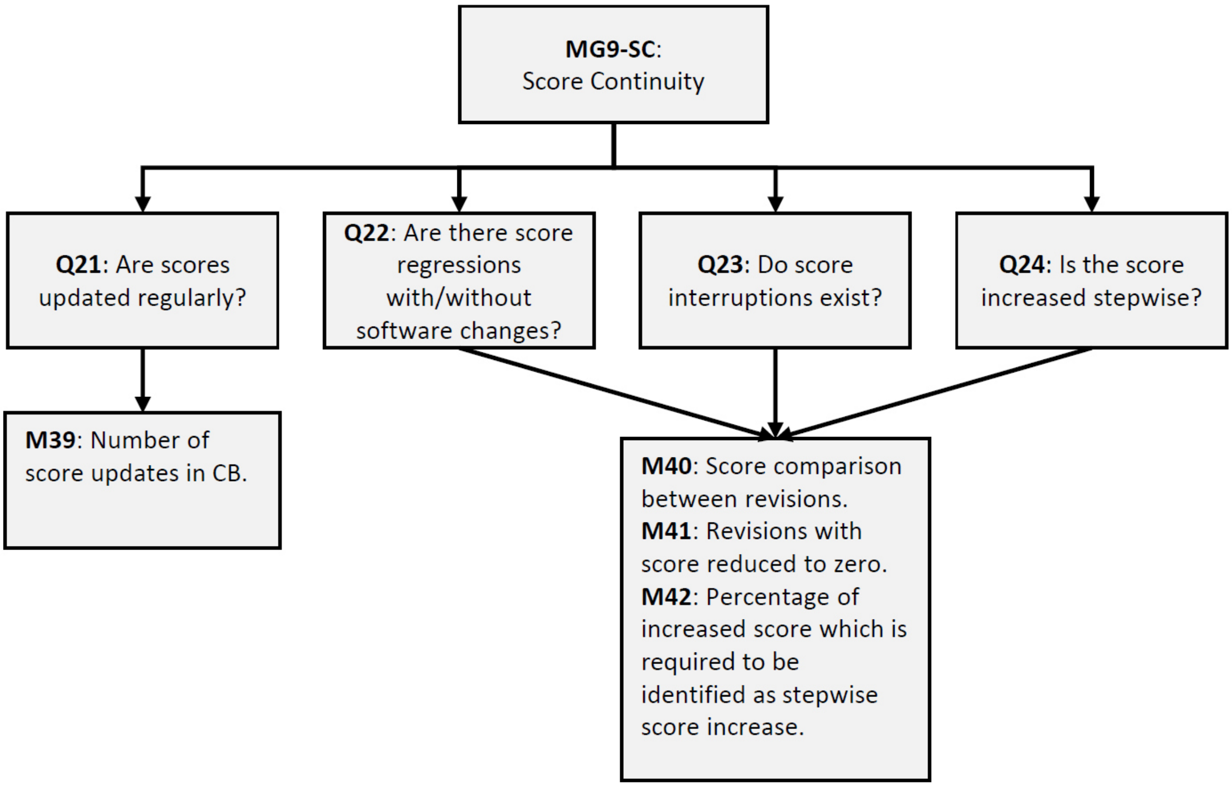

Figure 18: MG9-SC: Score Continuity

In Figure 18: MG9-SC: Score Continuity, the graph for the measurement goal *Score Continuity* is shown.

The score update is fundamental because it creates the link between the calibration data management and the calibration process.

Question 21 targets the regularity of score updates. Since a score update is expected when calibration values are changed, the number of score updates in CBs is measured by M39.

Question 22 targets score regressions. If new labels are added to the software, the average score will decrease. This is normal and expected. If the score decreases without a software update, the score is either reset by accident or there is a technical issue which decreased the maturity.

With question 23, it is evaluated whether the score is always carried over from one revision to the next revision as is the case in question 14 for the documentation continuity.

With question 24, it is checked whether the score increases stepwise. A stepwise increase of average maturity of over five percent from one revision to the next means that the score is not updated frequently. The score is only updated before quality gates. If the score is updated in such a manner, it can be doubted that the calibration engineer really checked each label before increasing the score.

For M39, the score changes in uploaded calibration changes are measured.

For M40, M41 and M42, the score statistics of the whole revision are used to gather the required information.

Table 18: Measurement Goal: Score Continuity

Analyse	Number and relation of score updates in AVL CRETA
To	Motivate to update scores according to calibration changes; evaluate the number of score updates; reduce errors in score information (wrong score, reset of score)
With respect to	Calibration files uploaded by calibration engineers, component calibration processes, score definition
From the point of view of	Project Managers, calibration pilots
In the following context	Vehicle component calibration projects

3.1.2.12 MG Process Conformance

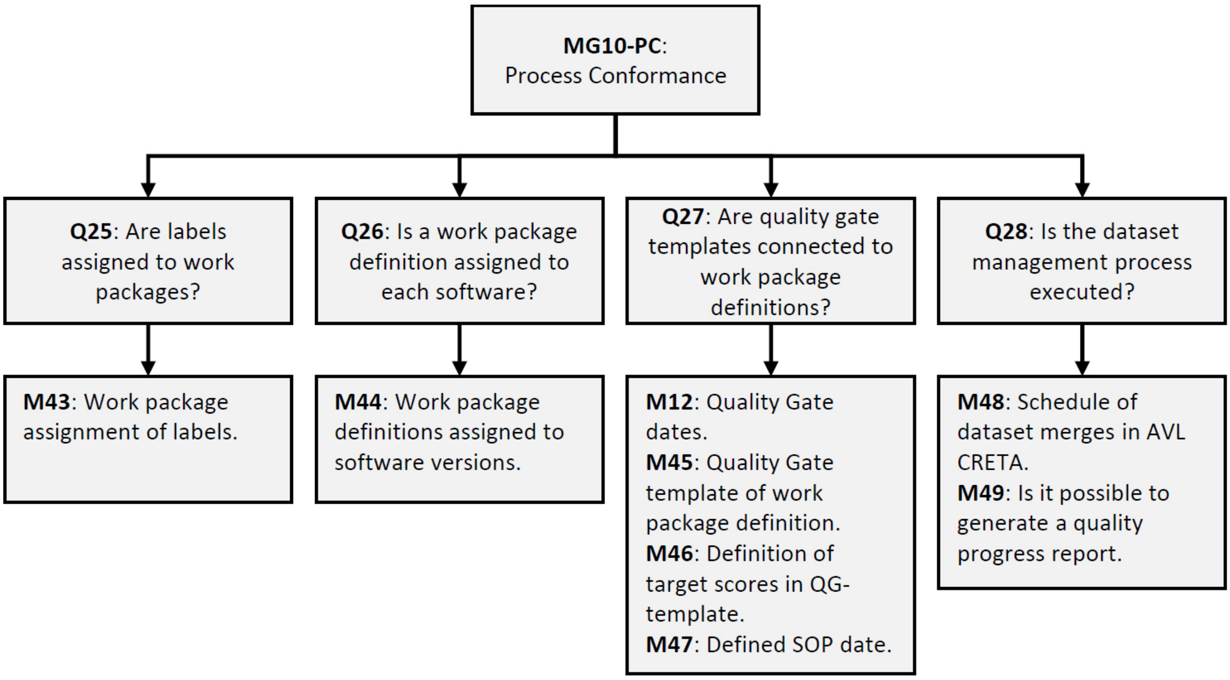

Figure 19: MG10-PC: Process Conformance

In Figure 19: MG10-PC: Process Conformance, the graph for the measurement goal *Process Conformance* is shown.

This measurement goal relates to the execution of the processes, namely the component calibration processes and the Dataset Management Workflow.

Question 25 relates to the work package assignment of labels. The work package assignment of labels is the basis for all calibration process regarding measurement and quality progress reports.

Question 26 refers to the quality gate template. The quality gate definition contains the relevant calibration process information like the number of quality gates, the work package names, the target scores for each work package and sub-work package as well as the number of days before start of production date, when the quality gate is scheduled.

In an SOP project, each software version should have assigned a quality gate definition.

Question 27 targets the quality gate template. The template is an excel template used to import the information required by the quality gate definition. If the quality gate template is missing, the work packages lack quality gates and target scores.

With question 28, it is evaluated whether the Dataset Management Workflow is executed in general and whether the label review meetings take place and new datasets are generated in AVL CRETA on a regular basis. It is also checked whether all requirements for the generation of the quality progress report are set up so that the quality progress report can be generated by AVL CRETA. This report shows the current maturity in comparison to the current target maturity for each work package.

M47 denotes the SOP date which must be set individually for each vehicle variant. This data together with the quality gate dates in the quality gate template is used to calculate the displayed quality gate dates in AVL CRETA.

Table 19: Measurement Goal: Process Conformance

Analyse	Conformance to the Dataset Management Workflow
To	Evaluate whether the Dataset Management Workflow schedule is met (label review meetings, work package assignments etc.); identify outstanding tasks to fulfil the Dataset Management Workflow requirements; enable target achievement reporting
With respect to	Dataset Management Workflow; project in AVL CRETA; Start of Production projects
From the point of view of	Calibration pilots
In the following context	Vehicle component calibration projects

3.1.2.13 MG Target Achievement

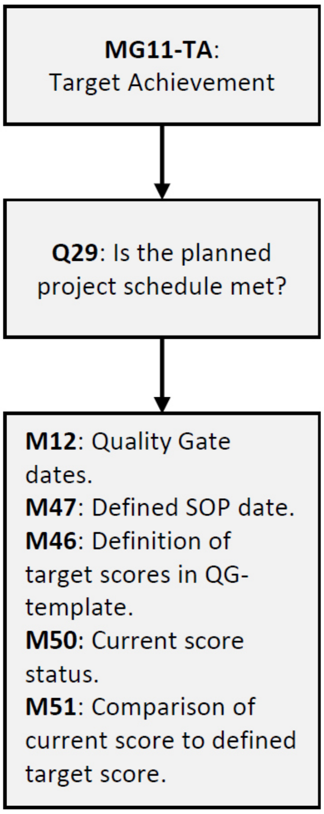

Figure 20: MG11-TA: Target Achievement

In Figure 20: MG11-TA: Target Achievement, the graph for the measurement goal *Target Achievement* is shown.

In question 29, it is evaluated whether the current quality progress is equal to or better than the expected progress. The metrics are the current status of the score, the defined target scores and quality gate information.

This measurement goal can only be attained if the quality gate process is set up correctly in AVL CRETA as evaluated in *MG Process Conformance*.

To evaluate the current quality progress, the information from MG10-PC is a prerequisite for the measurement of MG11-TA because the progress for the single work packages can only be measured correctly if the parameters were assigned. Missing parameter assignments or wrong assignments would alter the results of MG11-TA.

Table 20: Measurement Goal: Target Achievement

Analyse	Target achievement status
To	Evaluate the current status of the calibration progress; learn to better predict and recognise delays and timing issues; make the calibration progress more transparent
With respect to	Component calibration processes; process conformance, planned SOP dates, planned quality gate dates
From the point of view of	Project management, calibration pilots, calibration engineers
In the following context	Vehicle component calibration projects

3.2 Key Performance Indicators

Each GQM graph presented in 3.1.2.2 GQM Graph Details translates into one KPI. In this section, a calculation example of some of the KPI values with an already correctly defined formula will be given. A KPI calculation results in a number between zero and one. Zero means the worst result (the Dataset Management Workflow product in AVL CRETA is not visible or not sufficient) and one is the best result (the Dataset Management Workflow product was generated and is visible in AVL CRETA in all applicable cases).

The calculation of KPIs depends on weightings which must be adjusted and defined for different project types.

3.2.1 KPI Value Calculation

Calculation of KPIs is done per variant. All revisions valid for the CRETA Quality Dashboard in the target variant are analysed and the result (number of deviations) is stored. The deviations are weighted by their severity.

The first table comprises the name of the deviation and a description. In the second table, the name of the weights and a value proposal are indicated.

The formula depicts how the dashboard calculates the KPI value.

3.2.1.1 Score Continuity KPI

Table 21: Variables for Score Continuity KPI calculation

Variable	Description
N	Number of analysed Revisions
RegNoSwChg	Number of score regressions without software change
RegSwChg	Number of score regressions with software change
Interruption	Number of score interruptions

StepInc	Number of stepwise increase of score
CBNoUpdate	Number of calibration files with no score update but value changes

Table 22: Weights for Score Continuity KPI calculations

Variable	**Description**	**Value**
w1	Weight for interruptions	10
w2	Weight for regressions without software change	5
w3	Weight for stepwise score increase	2.5
w4	Weight for calibration files with no score update per revision	1
w5	Weight for regressions with software change	0

$$ScoreKPI = 1 - \frac{Interruption}{N}w1 - \frac{RegNoSwChg}{N}w2 - \frac{StepInc}{N}w3 - \frac{CBNoUpdate}{N}w4 - \frac{RegSwChg}{N}w5$$

The formula describes how certain states from Figure 18: MG9-SC: Score Continuity should be calculated to derive the KPI value.

3.2.1.2 Responsibility Conformance KPI

Calculation of the Responsibility Conformance KPI value is different for the variants of a project and for the software versions of the project. For the variants, the amount of permission violations in all calibration files is considered.

For the software versions in a project, the basis for responsibility conformance – the assignment of labels to owners and work packages – is analysed.

The weighting for combining the software and the variant rating has not been defined yet.

3.2.1.3 Responsibility Conformance KPI for Software

Table 23: Variables for Responsibility Conformance KPI calculation

Variable	Description
N	Number of labels in software
NoOwner	Number of labels with no owner assigned in software
DummyUserAVLWP	Number of labels with a dummy user but AVL work package
AVLUserCustomerWP	Number of labels with AVL user but customer work package
NoWorkpackage	Number of labels with no work package assigned

Table 24: Weights for Responsibility Conformance KPI calculation for software items

Variable	Description	Value
w1	Weight for unassigned owners	5
w2	Weight for WP assignment issue	5
w3	Weight for no WP assigned	1

$$SwRespKPI = 1 - \frac{NoOwner}{N}w1 - \frac{DummyUserAVLWP}{N}w2 - \frac{AVLUserCustomerWP}{N}w2 - \frac{NoWorkpackage}{N}w3$$

3.2.1.4 Responsibility Conformance KPI for Variant

The Responsibility Conformance KPI value is calculated based on all calibration files which were uploaded in the target variant.

Table 25: Variables for Responsibility Conformance KPI for variants

Variable	Description
N	Sum of label counts of all calibration files in variant
NoPermInAllCBs	Sum of all NO_PERM statuses in all calibration files

Table 26: Weights for Responsibility Conformance KPI for variants

Variable	Description	Value
w1	Weight for NO_PERM statuses in CBs	1

$$VariantRespKPI = 1 - \frac{NoPermInAllCBs}{N} w1$$

3.2.2 Current Status

The step to translate the GQM Graph measurement metrics into KPI values was only done for KPIs where measurements were taken (which were only those KPIs that were implemented in the CRETA Quality Dashboard prototype).

For other GQM graphs where the data is not collected in the prototype, a baseline for the current situation could not be derived and, therefore, the adjustment of weights and concrete calculation formulas was not possible although the pattern of calculation would have been the same for all KPIs.

3.3 Reporting

In this section, some selected examples of the generated reports will be given. Where no KPIs are calculated, the status is depicted by visualising the measurements (metrics).

3.3.1 Target Achievement

The target achievement reporting is done via a chart as shown in Figure 21: Overall Calibration Progress Chart. The border of one bar shows the target progress for one work package at one quality gate. The green bar inside shows to which degree the target is met. This report image illustrates a project after quality gate one.

The blue line shows the average target progress across all parameters. This means, the blue line is the mean target of all labels in all sub-work packages per quality gate.

The dashed line illustrates the current progress. Since the report was done shortly after quality gate one, the bars for the remaining quality gates are filled with the score of the lastly available dataset in AVL CRETA.

Since the number of parameters and even the distribution of parameters between the work packages may change due to software updates, the green progress bars and even the frames which represent the targets can be different when freshly generating the report.

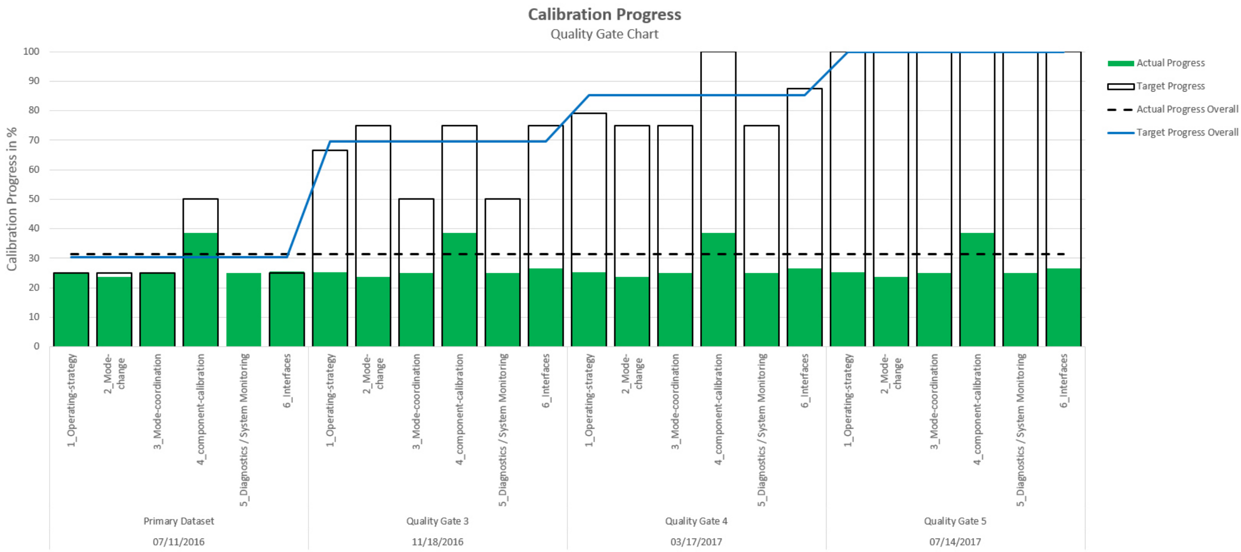

Figure 21: Overall Calibration Progress Chart

For each of the work packages shown in Figure 21: Overall Calibration Progress Chart, a separate chart like Figure 22: Calibration Progress Work Package 1 is generated. This chart presents the progress of the single sub work packages.

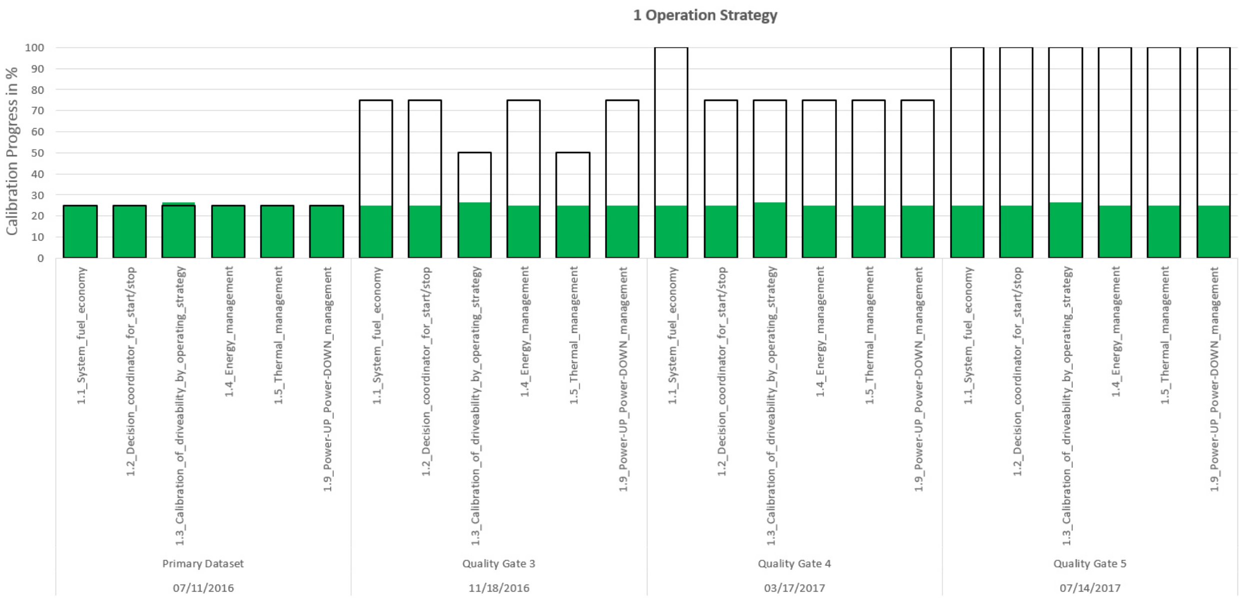

Figure 22: Calibration Progress Work Package 1

The progress in Figure 22: Calibration Progress Work Package 1 looks nearly the same for all quality gates. This effect occurs because at the time of generating the report the project schedule was shortly after “Primary Dataset”. For all later quality gates, the lastly available dataset in the target variant was used.

3.3.2 Score Continuity

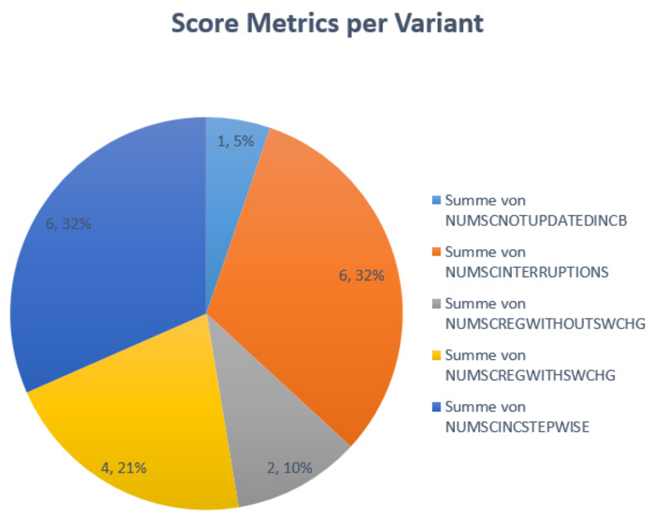

Figure 23: Score Continuity Status of Variant

Figure 23: Score Continuity Status of Variant shows the occurrence of deviations in one calibrated variant. In Table 27: Description of Score Continuity status, the different states are explained in short. Compare chapter 3.1.2.11 MG Score Continuity for more information.

Table 27: Description of Score Continuity status

Status	**Description**
NUMSCNOTUPDATEDINCB	Score was not updated in a calibration file although the file contained changes of calibration values.
NUMSCINTERRUPTIONS	After an import or merging of datasets, the score of the dataset decreased from above zero to zero. The set score

	was most probably reset to zero by a usage error of AVL CRETA.
NUMSCREGWITHOUTSWCHG	Number of score regressions without a software change. A change should not happen except when the hardware of a vehicle changes during the project, which is, however, unlikely.
NUMSCREGWITHSWCHG	Number of score regressions after a software change. A change can happen if the new software has new parameters which start at score zero. The average maturity of the dataset will drop.
NUMSCINCSTEPWISE	The score increased suddenly by more than 5% average score. This means that the score is not updated on a regular basis and the chosen score values are most probably not reliable.

During the analysis, the CRETA Quality Dashboard – Analytics Solution generates tasks which tell the CRETA pilot exactly in which datasets the unwanted score status occurred. Furthermore, the pilot is informed where he should take an action or at least where further investigation is needed.

3.3.3 Responsibility Conformance

Besides the ownership assignment of parameters and the work package assignment of parameters, the measurement goal Responsibility Conformance checks whether the uploaded calibration changes respect the set ownership of parameters. Compare chapter 3.1.2.3 MG Responsibility Conformance.

In Figure 24: Responsibility Conformance in Variant, the result of such an analysis is shown. In the depicted example, about 22% of all calibration changes where done by other engineers than the parameter owners. From these 22%, about 13% of the changes were accepted and merged into the next dataset. About 9% were not accepted and, hence, the value proposal was not merged into the next revision.

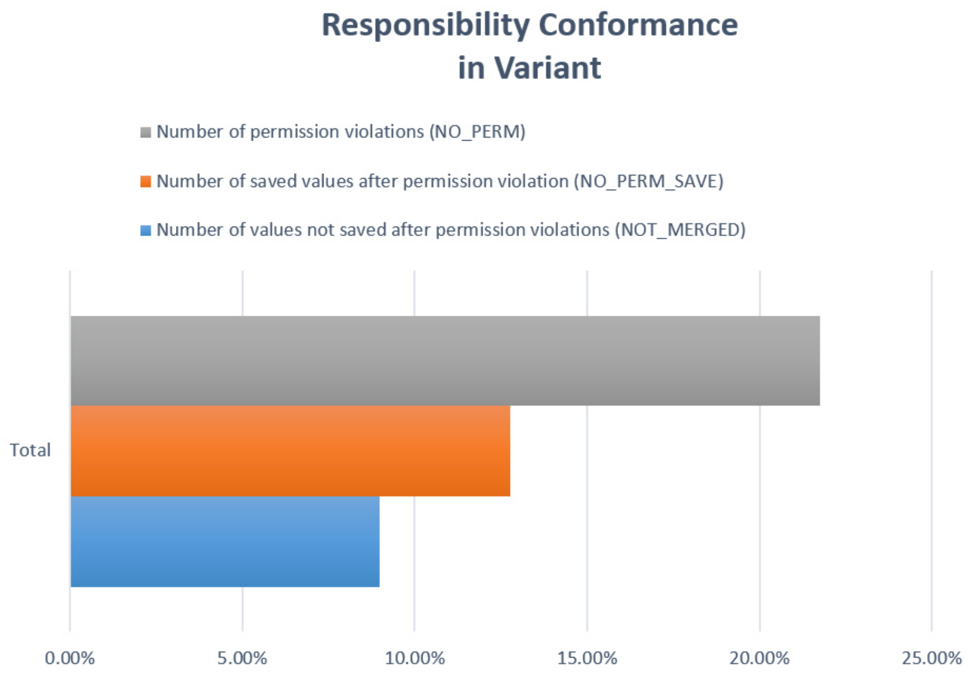

Figure 24: Responsibility Conformance in Variant

In this variant, there is much room for improvement because more than one change out of five was not carried out in conformance with the defined responsibility.

During the analysis, the CRETA Quality Dashboard – Analytics Solutions writes tasks to the CRETA Quality Dashboard Database which inform the user who is responsible for the permission violation where he changed the parameter from another user. Also, tasks for the actual owner of the parameter are generated to show him where a pending proposal for a value change is waiting for acceptance.

3.3.4 Calibration Continuity

In Figure 25: Calibration Continuity – Changes per calendar week and Figure 26: Calibration Continuity – Changes per project phase, the changes done in one vehicle variant over calendar weeks and project phases are displayed.

G-CG0 describes the changes which took place between the start of the project and quality gate one. G-CG1 describes the changes between quality gate one and quality gate two, and so on.

For now, the metrics only show where the calibration stopped. For further work, a baseline of reasonable number of changes has to be learnt, to see where a project displays an uncommon amount of changes and to predict whether the project will be delayed or finished before time.

Compare chapter 3.1.2.4 MG Calibration Continuity.

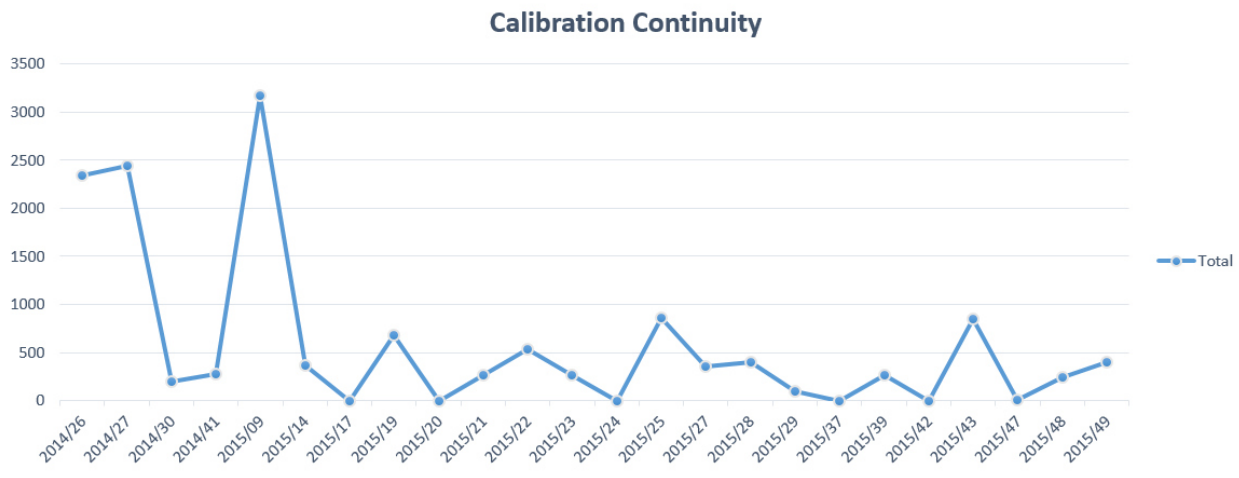

Figure 25: Calibration Continuity – Changes per calendar week

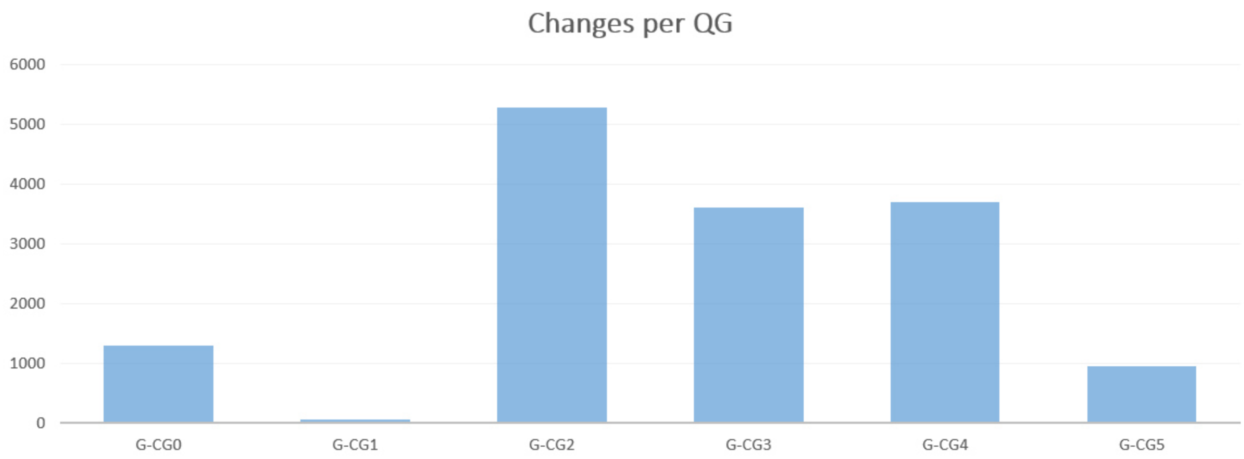

Figure 26: Calibration Continuity – Changes per project phase

4 Implementation

In this section, an overview of the prototype architecture will be given.

4.1 Scope

The “CRETA Quality Dashboard” (working title for the prototype) is limited to all required measurements for four KPIs. Those are:

- Score Continuity
- Responsibility Conformance
- Calibration Continuity
- Target Achievement

These KPIs were selected for the prototype because they partly lay the foundation for further KPIs. For example, the responsibility for calibration parameters must be defined for the customer and the AVL List GmbH before the Target Achievement can be evaluated. Also, the score has to be updated on a regular basis to enable the evaluation of the Target Achievement.

The Target Achievement was selected because the timing is nearly always one of the most critical topics in a calibration project and therefore important for all project members.

4.1.1 Subsystems

The implementation consists of three parts:

1. CRETA Quality Dashboard – Analytics Solution
2. CRETA Quality Dashboard – Add On
3. CRETA Quality Dashboard – Management Dashboard

The CRETA Quality Dashboard (CQD) Analytics Solution describes a backend server application which connects to the CRETA database via the provided CRETA API. It executes the measurements and aggregates the required data for the defined KPIs. Where deviations from the Dataset Management Workflow are identified, it also stores task items together with the information who the responsible user is. The statistics and results of these operations are sent to a database called the CQD-DB.

The CQD–Add-on describes an Add-on for AVL CRETA, which in the future should automatically be downloaded by each AVL CRETA client. The calibration engineer or calibration pilot can use the CQD–Add-on to access the information stored in the CQD-DB which is relevant for him. He should also be able to view the tasks which were identified and which he is responsible for.

The CQD-Management Dashboard targets department managers and project managers who are interested in a top-level view on the projects ongoing in their responsibility.

During the process of writing this thesis, the CQD-Add-on and the CQD-Management Dashboard are implemented as Excel Templates which have a data source connection to the CQD-DB. These templates have to be prepared for a certain project, vehicle variant or user and can be updated by refreshing the Excel sheet.

4.2 Customer Value

Customers of the CRETA Quality Dashboard are the calibration engineers and AVL CRETA pilots using AVL CRETA on a daily basis. Other customers are project or department managers who are interested in getting a compact overview of the ongoing projects they are responsible for. A summary of the most important points for each user group is shown in Table 28: User Viewpoints.

Table 28: User Viewpoints

Stakeholder Group	Benefit
Calibration Engineer	• Gets automated feedback about his AVL CRETA usage • Is informed about deviations and open issues regarding engineer tasks • Receives information when his actions are needed

	• Gets information what happened with his proposed calibration changes and his uploaded calibration files
Calibration Pilot	• Gets automated feedback about AVL CRETA usage • Is informed about deviations and open issues regarding pilot tasks • Gets supported by keeping an overview • Easier to generate reports and show state of the project from a dataset management perspective
Management	• Monitoring of ongoing projects • Degree of process adoption • Influence of software and hardware changes on calibration progress • Estimate time of target achievement

4.3 Architecture and System Specification

In this sub-chapter, a rough overview of the system specification which was created to outline the development of the CRETA Quality Dashboard prototype will be given.

The architecture is presented in an abstract description of the system components, while the presented key scenarios and use cases are described from the end users' point of view.

All content of this chapter is based on Chapter 3.1.2 GQM Graph Definition and Chapter 3.2 Key Performance Indicators.

4.4 System purpose

4.4.1 Context

The Quality Dashboard for AVL CRETA is an Add-on which provides a quick overview of the current status of the projects in AVL CRETA.

The management is provided with measurements which show the information about dataset management quality. For further information, see 3.1.2 GQM Graph Definition.

An efficient monitoring of the projects should be possible using the CRETA Quality Dashboard – Management Dashboard.

The calibration engineer and calibration pilot use the CRETA Quality Dashboard – Add-on to get a quick overview about open tasks and to see the calibration quality progress of their projects.

The prototype solution will be used to evaluate the business value and to derivate requirements and specifications for later implementations.

Table 29: Subsystems of the CRETA Quality Dashboard and involved existing IT solutions

(Sub) System	Description
AVL CRETA Server	CRETA database where the projects are stored which shall be analysed
CRETA Quality Dashboard - Analytics Solution	Executable programme which is located on a server. The server has an automatically executed task which is scheduled once per day to analyse the projects in the CRETA database and hand the results over to the quality dashboard database. The application indirectly accesses the CRETA database via the AVL CRETA client using the CRETA API.
CRETA Quality Dashboard Database	Stores the calculated KPIs and the tasks for the engineer and the pilot
CRETA Quality Dashboard – Add On	Is executed via the CRETA client. The Add-On must get information about the currently logged in user (user SUID) upon start-up. The Add-On accesses the engineer and pilot service to collect the relevant information for the currently logged in user.
CRETA Quality Dashboard –	A front-end which provides the KPI with results of the project. Only the management has access to this solution which can be realised via a central solution like a SharePoint-page. The Quality Dashboard

Management Dashboard	solution does not provide a specific user permission system, so the external front-end solution has to support user authorisation (e.g. SharePoint permissions).

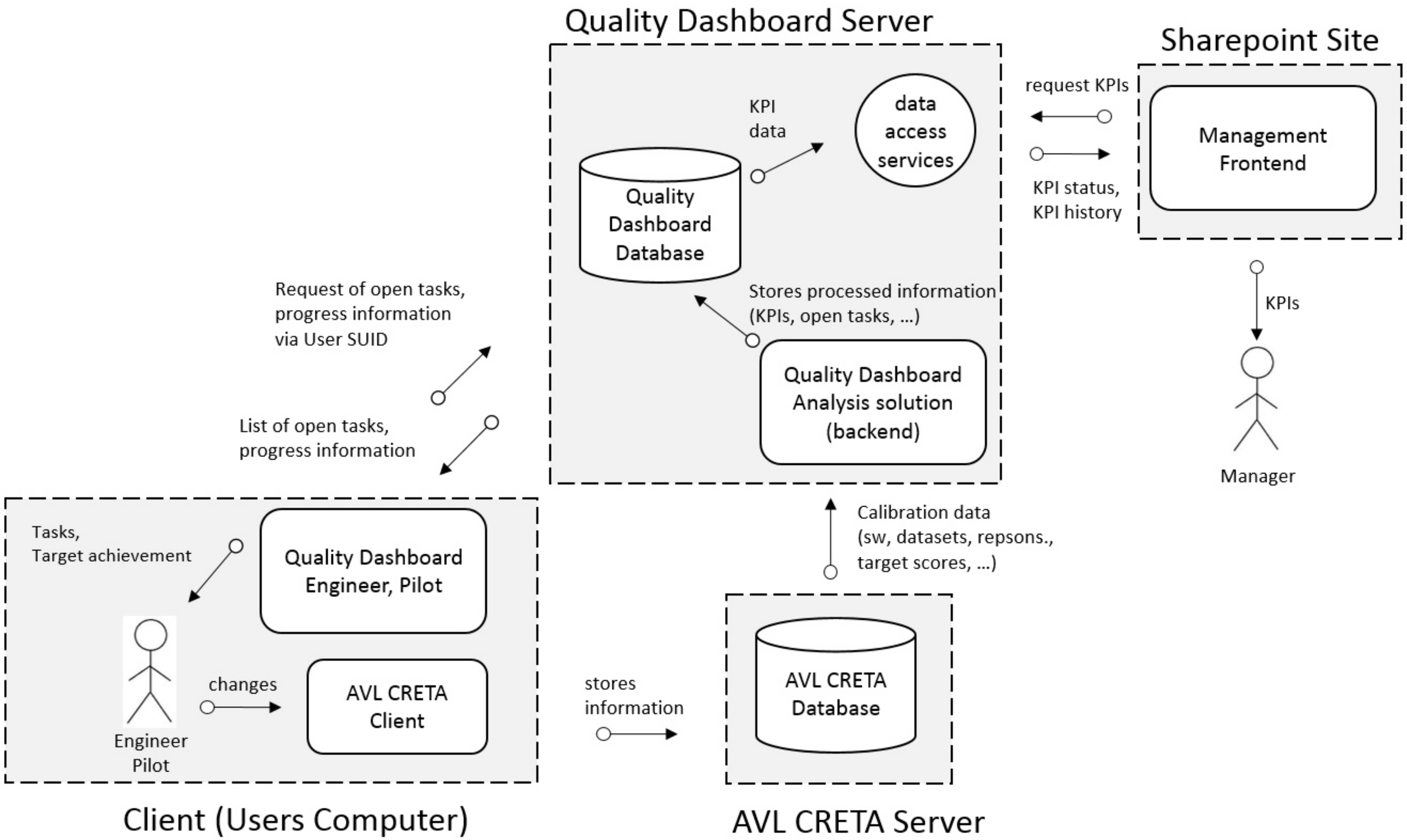

Figure 27: CRETA Quality Dashboard – Architecture Overview

4.5 System Interface

The Quality Dashboard analysis solution uses the CRETA API in order to access the CRETA database and gather the needed information to calculate the KPIs and create lists of open tasks.

Through the database interface, the stored information (KPIs, open tasks etc.) in the Quality Dashboard database can be accessed.

Since the CRETA Quality Dashboard is a prototype or proof of concept, the generated reports may be implemented in Microsoft Excel using the CRETA Quality Dashboard database as data source and the pivot chart features of Microsoft Excel for fast visualisation. Another advantage is that the Power Pivot feature of Microsoft Excel enables the readers of the reports to set their own filters or combine data of different database tables to review possible connection between the collected measurements and calculated results.

4.6 Non-functional requirements

The defined requirements are also restrictions to limit the effort for creating the prototype and make the task of implementing a working solution achievable in the given amount of time.

Chapter 4 Implementation and the contained specification were written after a first definition of the required measurements.

4.6.1 Quality Attributes

Table 30: Quality Attributes of the CRETA Quality Dashboard prototype

Quality Attribute	Note
Availability	The prototype’s availability cannot be guaranteed. During and after updates, software changes, configuration changes and server maintenance or after software failure, the system may be offline. The system will not automatically make backups. It is assumed that the database server will automatically be backed up.

Conceptual Integrity	A coding style will be used and the documentation of the system and source code will continuously be updated.
Interoperability	Services for third-party applications are provided to read data. The analytics solution will use the CRETA API to access the AVL CRETA database.
Maintainability	The parts (database, business logic, front-end etc.) will be separated through interfaces to support later replacing single parts with better implementations.
Performance	At the moment, the performance cannot be predicted.
Reliability	The prototype's reliability cannot be guaranteed.
Scalability	At the moment, the scalability cannot be foreseen.
Security	The prototype will not implement a user permission system or any other authentication or authorisation mechanism. The system will only be available through intranet to avoid external access.
Supportability	A simple log file in case of exceptions or system failure will be implemented for development purpose only.
Testability	Test cases for important parts of the system will be implemented. There is no guarantee of a certain degree of test coverage.
Usability	The prototype will provide a front-end for the engineer, the pilot and the management containing the defined information. No special usability testing or evaluation will be carried out.

4.6.2 General assumptions and restrictions about quality

For using the system as a product or as long-term business solution a detailed investigation about the non-functional and functional requirements must be made.

The target implementation of the prototype is considered as case-study and proof of concept and therefore does not meet the required level of quality normally expected by an end-user.

4.6.3 Key Scenarios

Table 31: Key Scenarios for the CRETA Quality Dashboard

#	Scenario
1	**Nightly task for calling the analytics solution and analysing the projects** The server running the analytics solution should accomplish a task which executes the analytics solution once per day, namely in the evening, for calculating the results during the night. The analytics solution analyses all projects which are enabled for quality dashboard. Disabled projects are projects which are not actively running anymore. The execution of analysis should be configurable by a project attribute in AVL CRETA. The analytics solution analyses all datasets and software versions in enabled projects which are not excluded via an attribute in the dataset or the software. This feature is needed because there are software versions and datasets which are uploaded for documentation purpose only and are not part of AVL's calibration responsibility. The project pilot must have an option to exclude these datasets for keeping the analysis output accurate. Concerns: • Performance: Since projects could have hundreds of vehicle variants and a vast amount of data has to be analysed and no caching is implemented, performance will be an issue for the prototype solution. • As the analysis of elements in AVL CRETA is selectable by setting a Quality Dashboard Attribute to Yes/No, the results of the analysis may vary when the pilots of a project change the attribute.
2	**Database access and storing of analytics results** The analysis solution stores its data in a database. A list assigned to the project with open tasks is kept for every engineer and pilot. Also, a calculation of the KPIs is stored for every variant. The list of open tasks must include the user SUID of the responsible person.
3	**Connection from management front-end and collection of stored KPI summaries**

	In the database, a list of the analysed projects for each day should be available. It must be easily traceable which projects were analysed over time. The KPI data should be sorted per project. A search for the project number must be possible (carried out via the project attributes). Concerns: • In what way are projects handled where the work is divided into different project numbers, while in AVL CRETA there is only one project (e.g. there is a project running for several years; each year, there is a new offer with a specific project number or a hybrid project where the different components are calibrated in different organisational projects)?
4	**Generating a project report over time (A3/A4)** KPI reports should be printed in formats like A4 or A3 to be able to show them in presentations.
5	**Access of Engineer/Pilot from the Quality Dashboard Client to the QD DB** Every CRETA User should have the possibility to start the Quality Dashboard via the CRETA Add-Ons. A locally stored Quality Dashboard client application (client) is executed. The client is started from CRETA and receives an XML file as input parameter which must contain the SUID of the calling user. The client connects to the quality dashboard server and requests the open tasks and other information (e.g. state of the quality progress for the labels of the defined user). This information is transferred to the client and displayed to the user. Since the current situation is validated not during runtime but on a daily basis, there is no live update if the user solves a not accomplished task (e.g. if he comments something which was a not completed task because a value change had not been commented), he will see the results the next day.

4.6.4 Application Overview

The application is a distributed client-server application. The quality dashboard client for the engineers and pilots will be developed as a CRETA Add-On.

The solution will be implemented in C# using the .NET Framework and Oracle Database solution.

Regarding licenses, the “Microsoft Visual Studio Express 2013 for Desktop” is used which is free of cost for commercial and private use. For the Oracle Database, an existing server is used and only a schema is added.

The server also provides services for accessing data or providing information to other front-end solutions than the quality dashboard client.

4.6.5 Candidate Solutions

Architectural spikes and prototype solutions for the critical parts of the system will be implemented first to evaluate key scenarios, issues and constraints before beginning the next iteration of architecture.

5 Conclusion and Future Work

The organisational goals behind the requirement of defining KPIs were identified and an approach for evaluating the current situation in dataset management quality was selected.

The Goal Question Metric approach was adapted to the field of vehicle calibration dataset management. GQM graphs were defined for all KPIs. A software solution was implemented to support automated measurements regarding three KPIs which were selected for the prototype.

The front-end management reporting was implemented as Microsoft Excel template using data source and pivot chart features to enable a fast generation of reports.

At the end of this thesis, the foundation for a quality improvement programme is now laid and the implemented prototype can be used to evaluate the business value and start doing GQM+Strategies iterations on a regular basis.

As a next step, the following can be proposed:

- Obtain measurements for different project types and vehicle components to evaluate a current baseline of Dataset Management Workflow capability and quality in the different departments
- Evaluate how the selected models correlate with the success of calibration projects and refine the models accordingly
- Make the CRETA Quality Dashboard – Add On available to the calibration engineers and evaluate the effect on the dataset management quality
- Integrate other performance measurements like AVL Drive for evaluating drivability and evaluate the correlation of the KPIs with the drive ratings
- Evaluate the impact of comparing projects and making the dataset management quality of projects visible for all affected parties (calibration engineers, AVL CRETA pilots and project managers)

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Figures

Tables

Abbreviations

.A2L	Label definition file format, ‘Software’ in AVL CRETA
ASAM	Association for Standardisation of Automation and Measuring Systems
CB	Calibration file
GQM	Goal Question Metric
.HEX/.s19	Dataset file formats
.par/.dcm	Calibration data exchange file format
QG	Quality Gate
SPICE	Software Process Improvement and Capability Determination
XCU	ECU, TCU, MCU; placeholder for control units