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Managing design guidelines for production development

A case study at Volvo Car Group

Master Thesis

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Department of Product and Production Development
CHALMERS UNIVERSITY OF TECHNOLOGY
Gothenburg, Sweden 2015

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Abstract

Time to market has become an increasingly important challenge for many companies, especially in the automotive industry. An important part of the time needed to get a new car model to market is to ensure there is a production system setup to handle the new model. This means that the engineers designing and updating the production environments for new cars must take many factors into consideration. The engineers at the Manufacturing Engineering department at Volvo Car Group could improve their productivity by having easy access to the information they need for production design. Information concerning requirements are today made available in specific databases and a similar database solution for guidelines would add value to Volvo Car Group. A database of guidelines to be used within the Manufacturing Engineering department at Volvo Car Group was the goal of this master thesis. After some initial research it was clear that the role of guidelines needed to be defined to clarify what guidelines are, how they should be used and what kind of information should be kept in a database of guidelines. Literature research together with interviews and a survey at Volvo Car Group was conducted to come up with a definition of a guideline, together with some supporting criteria make the role of guidelines clear. Some existing guidelines were analyzed using the definition and criteria to see the real world implications of them. Two examples of good guidelines were written to show what should be included in a good guideline and what kind of work is needed to come up with a satisfactory end result when writing guidelines. Sources in literature was combined with interviews at Volvo Car Group to come up with high level functionalities for a system to manage a database of guidelines. Some usability tests were conducted in Microsoft SharePoint to test out some basic guidelines management functionality and to find issues which may affect the user experience. This master thesis may also affect the time to market positively but to what extent is not known, partly since the time frames of such issues are company secrets. Future research could be used to make a fully functioning system for managing guidelines and also to come up with a framework to assist distinguishing requirements from guidelines.

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Anders Samuelsson, Göteborg 2015-05-18.

Abbreviations

BiW	Body in White
BMS	Business Management System
CAD	Computer Aided Design
CE	Concurrent Engineering
CW	Cognitive Walkthrough
DFM	Design For Manufacture
DGM	Design Guidelines for Manufacturing
FMEA	Failure Mode Effect Analysis
H&FDG	Hood & Fender Design Guidelines
HTA	Hierarchical Task Analysis
JPH	Jobs Per Hour
KPI	Key Performance Indicator
KRI	Key Result Indicator
LL	Lessons Learned
ME	Manufacturing Engineering
MEGMAS	Manufacturing Engineering Guidelines Management System
MTBF	Mean Time Between Failure
OEE	Overall Equipment Effectiveness
P&M	Purchasing & Manufacturing

PHEA	Predictive Human Error Analysis
PII	Process and Inspection Instruction
PKI	Process Control Instruction (Process Kontroll Instruktion)
R&D	Research & Development
RQ	Research Question
TCr	Team Center requirements
VCG	Volvo Car Group
VCM	Volvo Cars Manufacturing
VCME	Volvo Cars Manufacturing Engineering
VCMS	Volvo Cars Manufacturing System
VMR	Volvo Cars Mandatory Requirements
VPDS	Volvo Product Development System

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1

Introduction

INTRODUCTION will introduce this master thesis and present the situation that brought on this work. First the context of the subject is presented to give the reader an understanding of the automotive industry in general. Next, Volvo Car Group is presented and a brief background to the company in general is presented. Three short sections follow to give readers with less experience of Volvo Car Group a bit more detailed descriptions of three important areas of their business.

The automotive industry is in constant state of change and development due to ever increasing competition and stricter legislation to diminish the environmental impact. Sustainable development is considered all throughout research & development, production and for the complete lifecycle of the cars. Environmental impact, economic considerations and a sustainable working environment for all employees are goals that all need attention. A balance between these aspects is needed. Clear requirements and guidelines are needed to make sure that both the production and the products (cars) themselves consider and try to live up to the aspects previously mentioned as well as possible, while achieving a good balance between them.

During early stages of new automotive development projects, the capability and configuration of current processes and equipment are investigated and adapted to the new models. Manufacturing requirements and guidelines at different levels are developed and identified. This work-flow usually goes in parallel with other work-flows in order to get to the maturity requirement level as soon as possible. How long it takes from development until a product is available (time to market) is very important for a company to handle competition. Any extra time spent on development will delay the products market introduction and give the competitors a bigger market share. What is done during development and the number of steps will have a big impact on the overall time to market. This is especially important for the automotive industry due to the fierce competition it is characterized by.

Since the requirements and guidelines are so crucial to both the end result of projects and to the time needed for development it is an absolute necessity to manage them in a way that is robust, clear and efficient.

1.1 Volvo Car Group

Volvo Car Group (VCG) is a car manufacturer with its headquarters in Gothenburg, Sweden. VCG started its production in Gothenburg in 1927 (Volvocars.com, 2015). Zhejiang Geely Holding (Geely Holding) of China owns Volvo Car Group (Volvocars.com, 2015). VCGs range of car models include: SUVs, sedans, cross country cars, wagons and sports wagons (Volvo Cars in brief, 2015). VCG employed 22,317 people fulltime in 2014 (Volvo Cars in brief, 2015). Manufacturing locations of Volvo Car Group (Volvo Cars in brief, 2015):

- Sweden
  - Gothenburg
  - Skövde
  - Floby
  - Olofström
- Belgium
  - Gent
- China
  - Daqing
  - Zhangjiakou
  - Chengdu

VCG also has locations for design, Research & Development (R&D) and engineering in: Camarillo, USA; Copenhagen, Denmark and Shanghai, China (Volvo Cars in brief, 2015).

1.1.1 Car production

Car production starts in the body shop (A-shop), specifically in the stamping department, where rolls of sheet metal are unraveled and fed into the presses which stamp out components for the car body (figure 1.1 on page 4). The main parts of a car body are the floor (also called platform), the body sides (right and left) and the roof. Additionally, there are components that strengthen the main parts, these include the A, B and C pillars which strengthen the left and right sides. Each of the main components have their subcomponents attached, mainly through the use of spot-welding, of which, industrial robots handle the most of. In this process, operators monitor the robots while also providing them with components which are inserted into fixtures, to ensure a consistent position for the parts that the industrial robots spot-weld.

Once the main components have been completed, it is time to weld them together with each other. This happens in the "marriage point" in the body shop. When the welding is done and other components such as the doors have been attached, the finished car body is called a "Body in White" (BiW). The next shop for the car body is the paint shop (B-shop) which starts out by rustproofing the car body with many consecutive baths including phosphate, then electro coating is used to apply base coat of paint which finishes the corrosion protection for the car body. After this, sealing of all holes in the sheet metal which were needed during assembly in the body shop is performed, all weld joints are also sealed. Now the car body has the sealing needed to ensure that water cannot enter into the body, other materials that dampens noise and vibrations are also applied.

The car body is then cleaned to remove any residue which may interfere with the upcoming painting, the body also goes through an oven to harden the applied materials. Next, the car body is painted with many layers in a cleanroom environment to ensure a perfect painting result and finally many layers of clear coat are applied to make sure the result lasts many years.

The final shop for the car body is the final assembly (C-shop) or "Trim & Final" where production begins in the pre-trim area where the doors are temporarily removed to ensure that the operators can comfortably reach all parts of the car and to finish assembling the doors (S. Gedda, pers. comm.). Cables are put into the car body while in parallel the drive line is assembled by adding shock absorbers, engine, fuel tank and the exhaust system (S. Gedda, pers. comm.). Next, at the "marriage point" in the final assembly, the drive line is attached to the car body and then components such as seats, dashboard and safety equipment including many types of airbags are added. Pieces of trim are then added including the bumpers. The car then gets its wheels and gets filled with fluids such as fuel, oil and coolant, finally the doors are reattached. Software is then downloaded while checking that all the car's systems are working and after that, the car can come "alive". Finally, the car's performance is tested and inspections take place to ensure that the car meets Volvo Car Group's standards. Once the car passes the tests and inspections, it is ready to be delivered to its new owner.

1.1.2 Car development

Car development at Volvo Car Group is dependent on many processes of which the "annual process" is the first one. The annual process is not tied to development of a particular model, its purpose is instead to develop universal and modular solutions concerning product and production technology which can be used for many car models or car projects. Each type of factory (Body, Paint & Assembly) has what

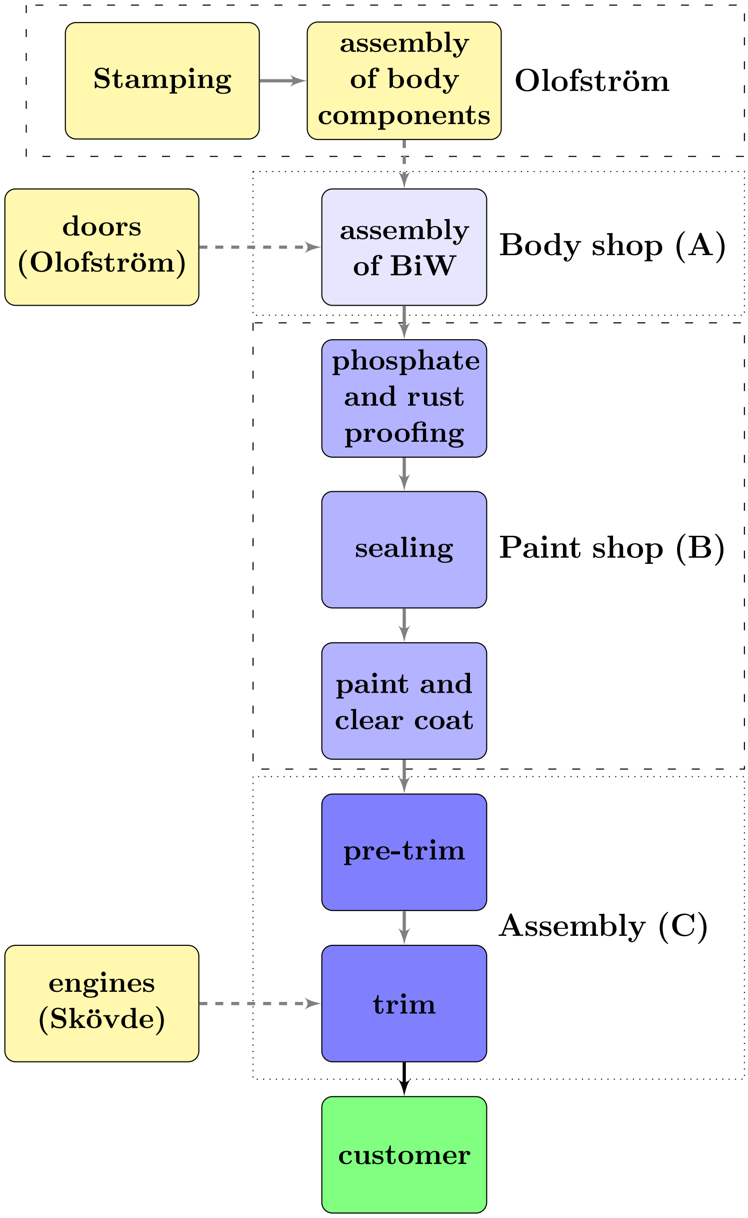


Figure 1.1: Simplified flow of the car production at Volvo Car Group's Torslanda plant.

is called "Core managers" with extensive knowledge about all processes involved in the production in each type of factory. The annual process also keeps contact and negotiates with suppliers to find suitable production solutions needed later in the car model development (S. Gedda, pers. comm.). This is done to capture synergy effects since there are many factories within Volvo Car Group, but also since the new models will later be produced alongside each other. The development concerning product solutions is also performed to find solutions that will work with many car models for functions that can be shared between them.

Development of a new car model is done in a project according to Volvo Product Development System (VPDS) (figure 1.2 on page 6). The first part of a new car project starts at "Product strategy & Vehicle Line Management" who has the responsibility to collect ideas and suggestions from; customers, different kinds of research, new technology and conclusions from earlier car projects to combine them and come up with designs for the new model on a high level. The "Manufacturing Engineering" (ME) department is becoming more and more involved at this stage and the goal is to increase and develop this work in parallel (Concurrent Engineering) even more (S. Gedda, pers. comm.). Later stages of this work is performed in collaboration with "Research & Development" (R&D) who will design the parts for the new car model, there are many checks of product feasibility to see if the concepts and ideas can be realized. While "Product strategy & Vehicle Line Management" focuses on functionality, R&D's focus is on making 3D-models and blueprints for the components needed to get the desired functionality into the new car model.

As the component designs become more refined, the R&D department starts checks with the "Purchasing & Manufacturing" (P&M) department to develop the systems needed to produce the new model and to start negotiations with suppliers for both components and production solutions. The ME department within P&M designs the factories and gives feedback to R&D concerning what is required of the designs so that the car can be produced, with the correct quality and at the right cost. These include components, solutions, processes and suppliers developed during the annual process combined with new ones. One example of requirements for the designs is to make sure there are points on the parts so robots can grip them, geometry which allows the robots access to perform spot-welding and openings where the phosphate can be emptied out. Allowing access for the operators during manual assembly must also be considered and to make sure that components can be attached while having suitable postures in terms of ergonomics. Physical test are then made to validate the product designs and to make sure the production processes work as intended with parts for the new car model.

The last main part of the development concerns the changes to the factories, installing new equipment and to test its functionality. ME develops detailed workflows and accompanying instructions for the operators in all the applicable factories. Trail-runs of the new car model are made in the actual production environment in each factory to make final adjustments. When the new car model has been through the trails, all production processes fulfill all requirements and the finished car lives up to Volvo Car Group's standards, then it is ready for its market launch.

1.1.3 Manufacturing Engineering

Within P&M at VCG the ME department has the role of linking product development with production. ME has the mission to find the optimum balance between

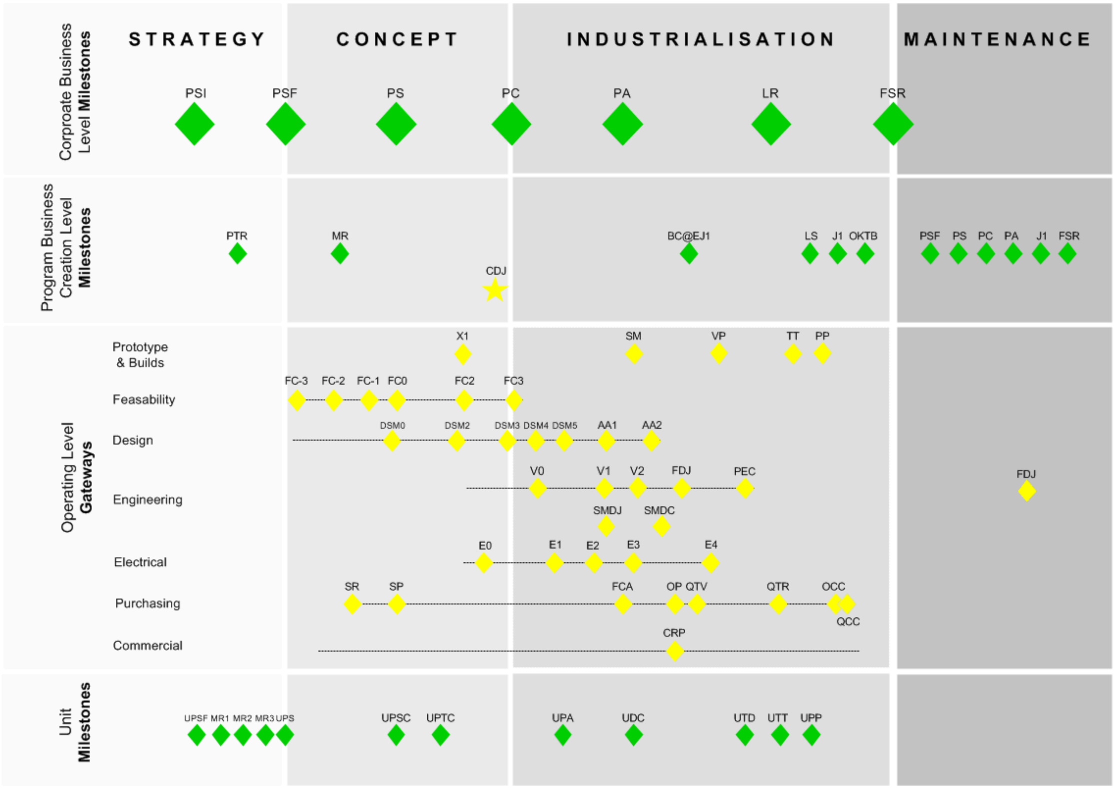


Figure 1.2: Volvo Product Development System (VPDS), source: Volvo Car Group (2015b).

product and production requirements in order to ensure an efficient production process. Manufacturing plants, which are the main customers of the Manufacturing Engineering department, are supplied with industrial strategy plans, methods, equipment installations and know-how through the use of product and process projects. Requirements and guidelines can be used to make it clear for engineers in different departments of what is needed and possible paths for solutions the engineers develop.

The current way of handling requirements and guidelines is something the engineers find unclear and it is also hard to find the specific requirements and guidelines due to different systems and many storage locations. Some parts of the development processes of VCG are currently divided into different tracks for the manufacturing locations due to local differences. The goal is to change this so that generic solutions can be developed which fit all locations. Ready of the shelf solutions that can be combined for each factory's need is a much more efficient and sustainable way of development.

Another long term goal is to be able to have 100% virtual capability, meaning that all development of products and production processes should be done in a virtual, software based environment. Trying to eliminate the need for physical prototypes is one very big step toward reducing the costs and the environmental impact, while simultaneously shortening the development times.

Today, many requirements are considered late in the development process and this should be as early as possible to lower the costs of development and reducing time to market. The development work for production begins with sequences for building the cars while equipment is handled much later in development. Product, process and tooling & equipment all need attention early in the development process to facilitate generic solutions that fit all manufacturing locations of VCG. The different systems and solutions should be verified as early as possible.

1.2 Purpose & Aim

The main purpose of this master thesis work is to contribute to a reduction in time to market by investigating, analyzing and suggesting improvements for the current management approach to guidelines. Due to the limitations with the current way of handling guidelines, a Manufacturing Engineering Guidelines Management System (MEGMAS) could make it easy for engineers to find information relevant to their work. A MEGMAS can also be used to provide an easy way of updating and managing all kept information. This database part can be especially useful when having personnel and consultants changes in the ongoing projects. A Clear definition of guidelines are prerequisites for the design process of the MEGMAS. This is the first important question to be answered in this master thesis and then the definitions will need to be adapted to fit within VCG. It should be noted that this work at the ME department is about manufacturing (production) development and it is not connected to development of products (cars) other than aspects impacting the manufacturing.

If the handling of guidelines was to be improved, the time to market could be reduced by making it easy for engineers to find up to date and relevant information. By having clear owners in the MEGMAS, any problems with guidelines can be forwarded to the persons responsible and users can make personalized lists of their current goals. Using the MEGMAS to store ready decisions, engineers can get updated, know what is decided and what problems still need solving.

The last main part of the thesis work is to perform interviews to find out what different departments would see in a MEGMAS and then to implement this in way that can satisfy as many as possible even though the specific requirements and guidelines in this thesis will be limited to the C-shop. Many user groups will also be interviewed to make the MEGMAS user friendly and to make sure that personnel with different backgrounds and experience levels can use the system.

1.2.1 Research questions

Key questions that the thesis will answer.

1. How can time to market for car development projects be shortened by removing uncertainties for engineers on where and how to find specific requirements/guidelines affecting their work by using a MEGMAS?
2. What are the differences between academic definitions of requirements/guidelines and the definitions used at VCG?
3. Is it possible to find definitions of requirements and guidelines based in academia that still satisfy the needs of VCG and if so, how should they be defined?
4. What are the important aspects of the MEGMAS which will be used to manage manufacturing design and development guidelines, how does that translate into specific functions?

1.2.2 Scope & limitations

This study will focus on manufacturing design and development guidelines concerning production from both structural and knowledge management perspectives. In other words, these guidelines will be investigated in terms of how they are developed, maintained, structured and updated; what improvements in their management lifecycle may contribute to their tacit value and productivity. Moreover, there is a necessity to develop visible boundaries between what requirements and what guidelines actually are. However, the difference will be studied on a generic level. Requirements and guidelines regarding product (car) development are not included since they are already handled in more structured ways with clear roles. Some basic comparisons will still be part of the thesis since the ways of handling product requirements and guidelines are good role models for the management of manufacturing design guidelines.

Furthermore, the study will be implemented at Volvo Car Group Manufacturing Engineering department, particularly in the C-shop (trim & final Assembly) at the Torslanda plant due to its high complexity from manufacturing design guidelines perspective, this includes the beta MEGMAS. The reason for that is to capture a more dynamic picture for the development trajectory of the guidelines and the difference in the way they were managed. Current and suggested guidelines will be categorized, analyzed and used when deciding what types of information should be stored in the beta MEGMAS. For the later topic, suggested easy-to-use functionalities will be developed/adapted, tested, analyzed, and validated through focusing on limited groups of key users who range from novices to experts.

2

Current state

CURRENT STATE will describe the state of VCG at the start of this master thesis by showing how guidelines are used. The related terms: requirement, KPI and standard will be presented with information about usage but more importantly, why they are at risk of being mixed up with guidelines. This motivates why so much effort is being put on defining guidelines as presented in the chapter "5 Results" with the actual work with the definition in the section "5.3 Defining a guideline".

2.1 Guidelines

The current role of guidelines at VCG is a bit fuzzy compared to requirements, mainly due to a less structured usage and different opinions of what a guideline is. How guidelines should be used differs between departments and individual users as shown in this section.

2.1.1 Guidelines at Volvo Car Group

The degree of comprehension in guideline documents within Volvo Car Group is varied. There are many uses of guidelines depending on where in VCG they are used. This leads to many documents about guidelines with varying degree of extensiveness and comprehension. Some documents contain very specific information (Volvo Car Group, 2015c) while others are used for illustrative purposes (Volvo Car Group, 2015d). A desired course of action is combined regulations in other departments to make guidelines (Volvo Car Group, 2015e). In short, the uses of guidelines at VCG are to support requirements, criteria for requirements, remarks and comments, clarifications and conditions which must be fulfilled.

2.1.2 Design Guidelines for Manufacturing

“Design Guidelines for Manufacturing” (DGM) is a 56 page document stored in the Business Management System (BMS) of Volvo Car Group (VCG) with detailed information about the six main knowledge areas. DGM fills the role of providing knowledge and guidance during the design phase of a production system (Volvo Car Group, 2015a). DGM is a document where information related to process design is stored.

Material flow in DGM is the most developed aspect with more expert knowledge, even though it is not finished (Volvo Car Group, 2015a). The guidelines and other information in “Material flow” is then the most important input for the definition of a guideline and when comparing with literature. DGM is a half empty shell which needs to be filled with the help from experts by providing guidelines and other knowledge (Volvo Car Group, 2015a). It is however a work in progress, meaning that the information is not complete and of course, like most information about technology, must be updated regularly to stay valid.

There are no requirements in DGM meaning it is a nonbinding document (Volvo Car Group, 2015a). Even though DGM do not include any requirements, it must not be disregarded since the information is very useful and related to VCG performance objectives. DGM provides guidance towards best practice (Volvo Car Group, 2015a). This aspect is closely related to knowledge transfer, both within and across departments. Since expert knowledge from personnel with a lot of experience is present in DGM it is a way of giving people with less experience access to this information. DGM cannot replace conversations between these two groups but it can provide a starting point to begin process design which means the expert can be involved later and this also lets the less experienced person “grow” during this work.

2.1.3 Purpose and use of DGM

Work standardized with DGM, brings clarity and conformity to projects for production development (Volvo Car Group, 2015a). The conformity aspect is especially important for process design at a company as a whole since the new processes must fit together with older processes and all shops must fit together with each other. Lessons learned provide continuous development of production development if they are used to update DGM (Volvo Car Group, 2015a). By learning from previous mistakes or finding improvements which can be implemented during later projects, DGM and accordingly, process designs will be continuously developed. DGM provides knowledge about what to consider when designing a production system by acting as a general framework (Volvo Car Group, 2015a). This means that the current DGM are more suitable during early design rather than later stages. Here is then room for improvement by including guidelines for other parts of the process design projects. Additionally, the current DGM are not finished in terms of adding current information. The DGM will never be finished for all time but they can be up to date and finished for the time being.

DGM provides knowledge for people working with development of production systems, by providing important aspects which need consideration during this work (Volvo Car Group, 2015a). There needs to be balance between providing the important aspects while keeping the amount of aspects low enough, for people designing processes to take them into account and keeping track of them.

Possible production development processes, for which DGM is suitable, include: design of a new production system, changing an existing production system, adding new processes to the current production or when performing a study of product feasibility (Volvo Car Group, 2015a). There are many uses of DGM and many areas to cover which means the amount of information needed for this is very large. This will be very challenging to manage while keeping the DGM useful, up to date and keeping the number of guidelines at a reasonable level. What is a reasonable amount is of course dependent on how the guidelines are managed and here an improved system for DGM management can help.

How to use DGM

The intended use of DGM is made very clear in the beginning of the document and information on how to use it is also provided. DGM is more of a handbook than a checklist (Volvo Car Group, 2015a). Having a handbook can be useful during design work but this use is less suitable when the amount of information is large and then a checklist is more suitable, according to theory. This has to do with limitations of humans and the ability to keep many things in mind at once (Osvalder & Ulfvengren, 2009).

Descriptions and answers to the questions: “what?”, “why” and “how?” are used for all aspects (Volvo Car Group, 2015a). This is used to group the information to make it easy for the reader to find the information he or she is interested in.

“What?” describes the aspect and lists related aspects (Volvo Car Group, 2015a). Understanding what should be done and how the aspects are related to each other is fundamental knowledge but not always easy to understand, this is where the DGMs can provide guidance.

“Why?” describes what makes the aspect important and what in terms of performance objectives are affected by it (Volvo Car Group, 2015a). Relating the guidelines and aspects to the performance objectives give them credit and importance since the performance objectives are well established at VCG.

“How?” entails the guidelines to consider during production system development (Volvo Car Group, 2015a). The last aspect is to provide knowledge of how improve the process design by connecting the performance objectives with specific aspects and solutions. It is intended that the reader chooses among these three questions depending on what information is sought after (Volvo Car Group, 2015a). This can then help the reader to find the way in this document despite its considerable length.

2.1.4 Knowledge areas of DGM

Volvo Car Manufacturing Engineering (VCME) prepared DGM as support for: production system, finance, logistics, competences, work environment and product characteristics which are the main areas knowledge. Personnel within ME was the intended users of DGM and the main purpose was to have a place to store and retrieve important and useful information. The knowledge areas and some examples of corresponding sub topics are shown in figure 2.1 on page 13.

Communication between the above fields of expertise can save time, energy and money, if it is done in the early phases, it can facilitate getting it right the first time (Volvo Car Group, 2015a). DGM can connect the departments and areas to increase the understanding of work performed outside a team. Through this, the solutions can be adapted to fit each other and this can reduce the need for doing things over.

2.1.5 DGM and Volvo Car Group's Performance objectives

The DGM are also related to the performance objectives at VCG. The main performance objectives of Volvo Cars Manufacturing (VCM) (Volvo Car Group, 2015a):

- Quality
- Cost
- Delivery
- Improvement
- Safety
- Medarbetare (co-worker)
- Environment
- Leadership

The performance objectives can be improved during production development by using the guidelines in DGM (Volvo Car Group, 2015a). This gives additional motivation for why the DGM are important to take into account during process design.

2.1.6 Origins of DGM

DGM, the document started as a master thesis by Magnus Carlred and Henrik Ericsson (Carlred & Ericsson, 2012) during the spring of 2012 at VCG (then Volvo Cars). Their work supervised by Jonatan Berglund (Chalmers) and Jan Eskilsson (Volvo Cars) aimed to start a framework of design guidelines to make development of production systems at ME standardized.

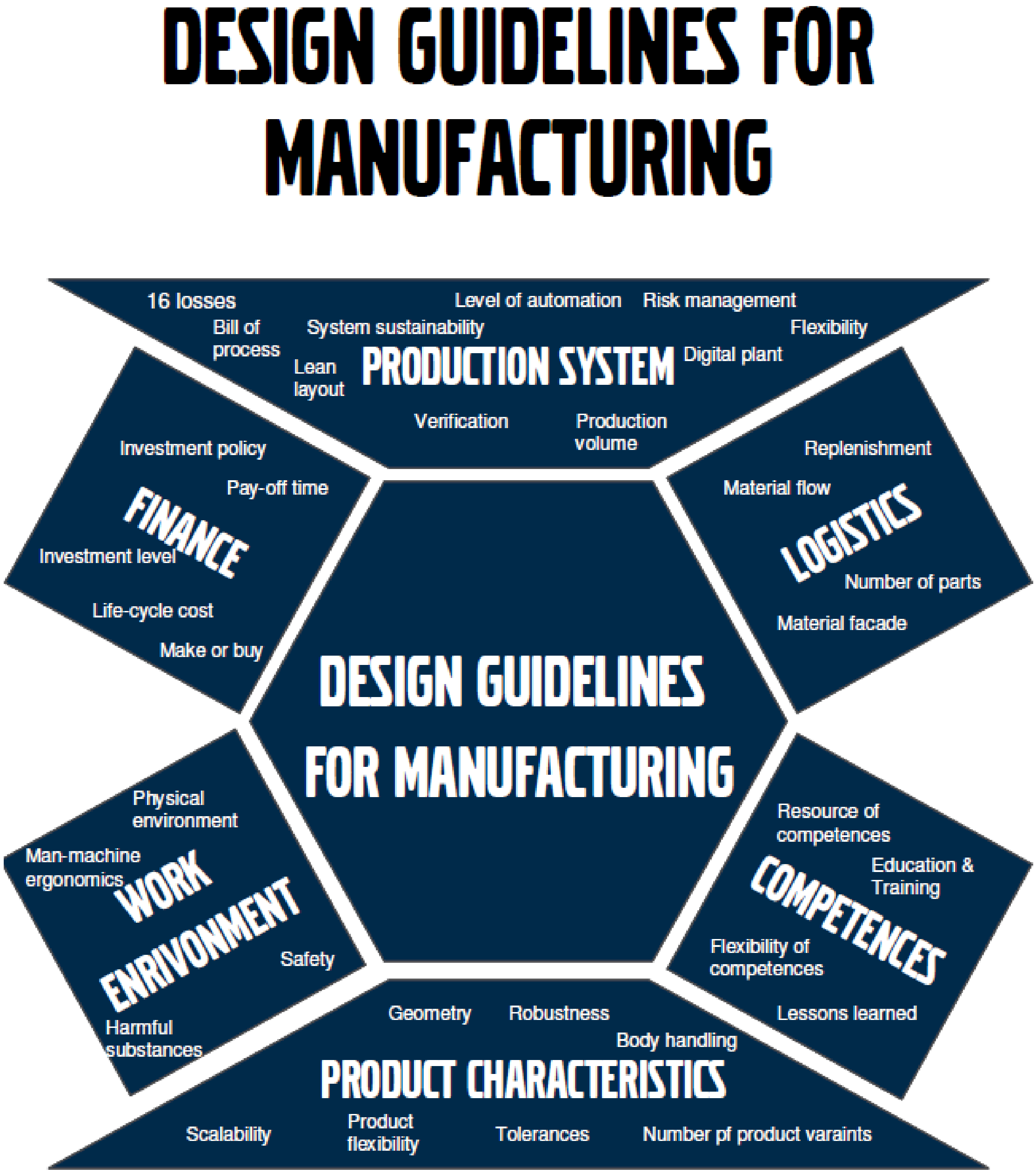


Figure 2.1: Design Guidelines for Manufacturing within Volvo Car Group, source: Volvo Car Group (2015a).

2.1.7 Guidelines comparison with "Hood & Fender Design Guidelines"

One example of a document which can be used for comparison with DGM is the "Hood & Fender Design Guidelines" (H&FDG) which has a similar purpose but for personnel at Research and Development (R&D). "Hood & Fender Design Guidelines" is a 75-page document with extensive knowledge about hood and fender, how to design them and other related information.

According to Volvo Car Group (2015b), engineers use guidelines when designing parts to get information about:

- Issues of previous designs (through lessons learned)
- Solutions to previous problems (lessons learned)
- Examples of good designs

H&FDG is used for: knowledge transfer, expert knowledge or to provide guidance to follow requirements/standards and ideas for future designs to further improve them (Volvo Car Group, 2015b). The aspect of knowledge transfer is a very important one, to ensure that as many people as possible are well informed with the current information and to provide support for employees with less experience. Ideas and input from lessons learned then provide the continuous improvement aspect to the readers and users.

H&FDG includes a lot of pictures of solutions and problems, both photos and CAD images. This way of showing blueprints and 3D-drawings can provide good support for an engineer with less experience with design work of hoods or fenders. H&FDG has a structure to make it easy for an engineer to find the specific information he or she is looking for but the length of the document may be an issue, at least for someone with less experience of using it. This document can also be useful for updating ones knowledge or when conveying issues to other departments.

2.2 Requirements

Requirements at VCG have a clear role with extensive descriptions of how to write and manage them. Both product and process have many requirements to make sure the sought after functionality is present. Requirements also have documentation on how to write and manage them which is not the case for guidelines. The document "Requirements Guideline" lists guidelines with description of how a requirement should be written. "Requirements Guideline" provides six main aspects to consider when writing a guideline (Volvo Car Group, 2015f):

- Traceability
- Purpose
- Clarity

- Completeness
- Validity
- Verifiable

These aspects are closely related to literature on the subject, such as: "Requirements Engineering" (Hull, Jackson and Dick, 2011). It is clear that "Requirements Guideline" has very clear connection to literature on the subject, giving it extra credibility. One can follow the steps in the guidelines to come up with a good and usable requirement. Lastly, the newly written requirement must go through a quality check and be documented (Volvo Car Group, 2015f). "Requirements Guideline" provides examples which are bad and ways of improving them.

Requirements for car models are stored in the system "TeamCenter Requirements" (TCr) at VCG (Volvo Car Group, 2015g). TCr provides the aspects of requirements management for both authors and users. There are clearly defined systems for handling requirements and associated workflow at VCG which means the requirements management is well thought out.

"Volvo Cars Mandatory Requirements" (VMRs) are specific functionalities or minimum level performance of car models and their accessories (Volvo Car Group, 2015g). VMRs are connected to laws and regulations, FMEAs and company strategies among others (Volvo Car Group, 2015g). All of these aspects will of course be used to live up to the customer's expectation while fulfilling VCGs core values. VRMs have clearly defined sections which explain: purpose, who are concerned, responsibility, execution, documentation and a list of references to provide more information and background (Volvo Car Group, 2015g). The execution section of VRM lists step by step how to: revise or create a new requirement, how to handle them in vehicle programs and what to do in case of nonconformance or deviations (Volvo Car Group, 2015g). It is very clear that requirements at VCG are handled well and thoroughly.

2.3 KPIs

A Key Performance Indicator (KPI) is way to use numbers with indicators to make a status clear, this also one of the uses for a KPI at VCG but there are more uses present. The following examples from VCG will be used to try to make this clear.

"Air Leakage Body in White" uses a KPI with a measurement of leakage openings in cm^2 where it is OK (green) if it is under 10 cm^2 and not OK (red) if it is over 10 cm^2 (Volvo Car Group, 2015h). Depending on the importance of the KPI, a safety margin using yellow to indicate the KPI being very close to not OK is added. If an opening is very close to 10 cm^2, for example 9.99 cm^2, the measured opening will be indicated as just as OK as other even if in reality there might not be a margin due to a measurement error. The way this KPI is apart from the previous fact used in a way which follows literature on the subject.

The KPI for "Drawn arc weld" on the other hand has defined different borders between ok and not, depending on when during development the KPI is analyzed and this is defined by the development milestones (Volvo Car Group, 2015i). During the early development stages, the "Drawn arc weld" has no yellow area but in later stages they are defined in addition to red and green which are present for all stages. Even though Drawn arc weld is called a KPI it is more of a set of requirements with the only number present is how many joints have passed these requirements and in the later stages, a checklist where the number of joints adhering to the checklist. This is one example of somewhat different way of defining and using KPIs at VCG, compared to literature. There are many more examples similar to this one at VCG, it is not necessarily a problem but it might cause some confusion.

"Underhålls KPI:er – Utbildningsmaterial" (Maintenance KPIs – Education Materials) (Volvo Car Group, 2015j) describes how to use and calculate KPIs related to maintenance, such as Mean Time To Repair (MTTR) and Mean Time Between Failure (MTBF) which are use the same way as in literature. There are clear instructions on how to collect the necessary data and then how to calculate the KPIs. Background information also helps out by explaining scenarios where and when these KPIs are useful.

This basically points out two types of usage of KPIs, of which only one has support in literature and academia . Changing the use or changing the term to something else is not a very appealing solution but VCG at least need to be aware of these differences. Some KPIs should also probably be improved to make use of more indicators than OK and not OK.

2.4 Standards

There are many standards concerning all parts of VCG, not only the cars. Both internal and external standards are used at VCG to support all departments. The main categories of "Standards for Volvo Cars" (Volvo Car Group, 2015k) are:

- Surface coating
- Material
- Design methods
- Parts
- Production equipment
- Information technology
- Administrative standards etc.
- Calibration procedures

- ISO standards

One example of a standard is a data sheet with descriptions of requirements for a component. This information can be used to send out requests for quotations from different suppliers while making sure the offered component lives up to requirements.

"Machine vision – General guidelines" (Volvo Car Group, 2015l), under the category "Production equipment", is a standard describing what is needed of a vision system for use in production. This standard gives the reader background and other useful information about such fairly complicated production equipment which is not very straight forward to put in a factory environment. "Machine vision - General guidelines" has three main goals related to standardization: fewer disturbances related to vision systems, common methods and less diversity in vison equipment (Volvo Car Group, 2015l). These three goals can of course apply to other production equipment but it is for more rare and complicated equipment where it is extra important to provide good and extensive documentation. There is a checklist which if fully fulfilled means the vison system is following the standard (Volvo Car Group, 2015l). This can help to point out risks of new installations by indicating unfamiliar territory of installations which do not adhere to the VCG standard.

"Machine vision - General guidelines" is an example of an internal standard within VCG and there are no national or international equivalents (Volvo Car Group, 2015l). One explanation for this could be the more recent technology of vision in production, where less cases and experiences are available from previous successful installations.

Standards are more clearly geared towards standardized solutions compared to design guidelines. This is extra important for new and complex technology. Similarly to requirements, standards are well defined at VCG, including the management of them.

3

Methodology

METHODOLOGY will provide information on how the work with this master thesis was performed. First, there is a small section about 'Research ethics' which will go through all the necessary considerations when collaborating with another person in an academic setting to make sure the rules are followed and in this case, adhering to two separate universities' rules. Next, the work towards selecting the methods for data gathering are presented together with theory on the subject which provided guidance during this work. There is a description of how the methods were used in the actual data gathering of primary and secondary data. Finally, some motivations of why the methods were selected and used.

3.1 Research ethics

This master thesis was performed in collaboration with Hafez Shurrab (Shurrab, 2015) who studies the master program "Industrial Engineering & Management" at Karlstad University. The gathering of suitable theory and data gathering of this master thesis has been a collaboration with Hafez but the content in this report has been written solely by Anders Samuelsson since he is the only participant from the view of Chalmers University of Technology. Every result in this report is however attributed to both Hafez Shurrab and Anders Samuelsson. The following analysis of the results and the discussion are all the work of Anders Samuelsson.

3.2 Choosing methods

This master thesis used qualitative research with primary data and secondary data (see below) within an industrial case study. The thesis work started with getting to know the situation at VCG using qualitative research and to get a grip on the

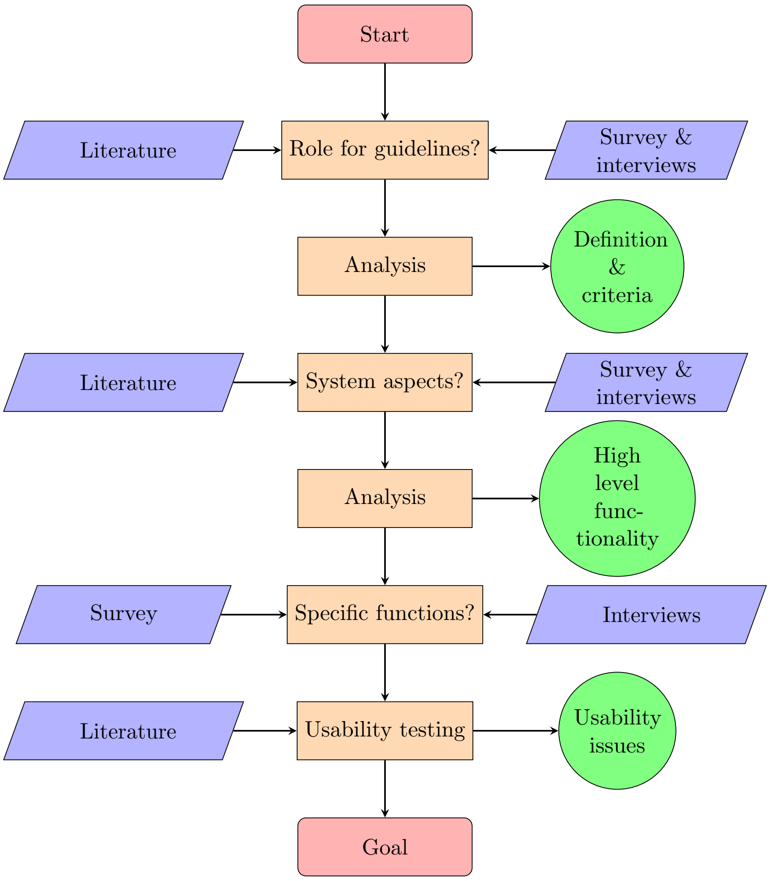


Figure 3.1: Basic research work-flow for this master thesis.

problem which served as the starting point for this master thesis. Time was spent in the beginning to get to know the ME department within the VCG organization. Unstructured interviews were part of this step as suggested by Osvalder, Rose and Karlsson (2009) when gathering qualitative data with limited understanding of the topic.

3.3 Primary data

The primary data came from personnel and computer systems within VCG, mainly personnel and systems related to the ME department. How this data was gathered is described below. Some of the first parts of this master thesis was spent on getting to know the right people and understanding the different internal computer systems at VCG and in the ME department.

3.3.1 Survey

The choice to use a survey for data gathering came from wanting to get opinions from many people in a short amount of time, for which, a survey is a good choice (Osvalder, Rose and Karlsson, 2009). A pilot study of the survey was performed first to verify the language used, complicated questions used fields for free text where the respondents could answer (from Osvalder, Rose and Karlsson, 2009). Microsoft SharePoint was used to make and manage the survey, providing an extra occasion for familiarization. The main results can be found under "5.2 Survey about guidelines" in the Results chapter.

3.3.2 Interviews

The first interviews were unstructured as stated above, some structured interviews were performed at a later stage. Combined with the structured interviews was also time for each participant to fill out a forms for some additional data gathering.

3.3.3 Company documents

Internal company documents were analyzed by using VCG's Business Management System (BMS) to search for content which could prove or disprove the theories related to this master thesis and to have a clear picture how VCG was doing things. The BMS had search functions which could be limited to document types (see "2 Current state") to help with the vast number of documents. Intranet and SharePoint page for internal use at VCG were also sources of information about the company and its departments.

3.4 Secondary data

Secondary data was collected from literature available from Chalmers library and other scholar resources (see "4 Theory"). The secondary data was collected to find theoretical support for guidelines, their definitions and their usages. Theoretical information about related terms and management approaches were also analyzed. How a system could be designed, how to achieve high usability and how to test a system were used as questions to try to answer with academic literature.

3.4.1 Literature study

The secondary data was collected from Chalmers library sources of academic literature in digital formats whenever available possible because of the ease of access. Keywords and concepts where entered into the library search functions and many search results were checked to see if the content could provide answers to any of the areas of uncertainty. Some results were found to not add any value because of similar content as already included sources, many of the results did not provide any clarity to the subject and were therefore not included. Literature used in previous courses during the bachelor and master's education with useful content were included. A few web page sources were included but sparingly, mainly when content of other sources were lacking.

3.5 Data analysis

The data analysis started with finding out what a guideline was and what purpose they serve at VCG. Next, the same kind of information was gathered from many literary sources to see if they agreed and what information there was about definition and purpose of guidelines. The gathering of data at VCG also made it clear that there were other terms which were sometimes mixed in with the guidelines, terms like requirement, key performance indicator and standard. What these terms meant was then gathered from literature and comparisons were made with the practice at VCG. These primary and secondary data sources were then analyzed and combined into a definition of a guideline together with criteria which can help to improve the quality of guidelines ("5.3 Defining a guideline" in the Results chapter). All this was needed to understand the guideline and to find out what kind of information the system which would manage the guidelines would need to contain.

Information which could serve as input to the system was then gathered from literature with a lot of usable information from interviews and the previous survey. Some tests were made in SharePoint to come up with and test out functionalities. A few of the functionalities were tested out for usability issues with help from the information gathered from literature ("4.7 System testing" in the Theory chapter).

The long list of high level functionalities were narrowed down with help from the tests in SharePoint which gave insight into what was possible in the time available. Interviews were used to verify and prioritize the list of high level functionalities.

4

Theory

THIS SECTION will introduce the literature and theories that provide the foundation for this master thesis. First of all, there are some terms that are central to the thesis that will need definitions and analysis of how they are used in literature. Guidelines are the main issue for this master thesis and they have to be clearly defined but there also needs to be a clear role for them in the development flow while having clear borders to other terms that are related. Requirements are very important in development but their role is different to guidelines and in order to have the clear borders between the terms a definition is required, together with the respective roles. The term KPI is also analyzed in this section and why it is included will become more clear in the "5 Results" chapter. After that, a few engineering strategies are presented to give a background of their benefits and limitations, what business environment they are suitable for and prerequisites for their usage. Theory sections in this chapter:

4.1 Guidelines

4.2 Requirements

4.3 Standards

4.4 Key Performance Indicators

4.5 Concurrent Engineering

4.6 Information system design

4.7 System testing

4.1 Guidelines

While there are many sources in literature about requirements in terms of: defining them, writing them, auditing them and managing them, this is not the case for guidelines. The term guideline leaves much more room for interpretation and its usage differs in literature. If guidelines could be given a clear definition then the role it has alongside standards, requirements and KPIs would be more apparent. This lack of available definition means that one would have to go on dictionary definitions and uses of the word guideline in literature on the way towards a clear and usable definition. If this is the case then combined with uses and informal definitions in practice, a suitable definition might become evident.

4.1.1 Available definitions of guidelines

A good place to start when working towards a definition of guidelines is to start with definitions in dictionaries. Many dictionaries are available and analyzing both common dictionaries and specialized dictionaries could shed some more light on guidelines. Only the parts of the definitions that applies are included while more literal meanings are excluded.

The "Longman Dictionary of Contemporary English" (advanced edition) is what might be categorized as a common dictionary without specialization towards a specific field. A guideline is defined in the following way according to the Longman Dictionary of Contemporary English:

1. rules or instructions about the best way to do something...
2. something that helps you form an opinion or make a decision

(*Longman Dictionary of Contemporary English*, 2009, p. 779).

This way of dividing guidelines into two parts indicates different uses but this can also been seen as guidelines having two main roles to fill. Another general dictionary is "Merriam-Webster" which definition is a bit different:

> a rule or instruction that shows or tells how something should be done
>
> (*Merriam-webster.com*, 2015)

Merriam-Webster has a more strict definition by saying guidelines provide information on how it should be done rather than just a recommendation. A third general dictionary "Oxforddictionaries.com" defines a guideline in the following way:

> A general rule, principle, or piece of advice
>
> (*Oxforddictionaries.com*, 2015)

This on the other hand is a very general definition which seems to include all kinds of help in guidelines. The last general dictionary "Dictionary.com":

> any guide or indication of a future course of action
>
> (*Dictionary.com*, 2015)

Dictionary.com basically defines a guideline as any information on how to act no matter how generic the description is, this definition is even more general than the one from "Oxforddictionaries.com".

Even from these four general dictionary definitions it is very clear that there is no clear consensus on what a guideline is and there is much room for interpretation. This mean that there is a lot of freedom when coming up with a definition but it also means that there is not much in terms of support.

By also checking what kinds of definitions specialized dictionaries use, one might get an understanding of how wide the definitions are spread. The next source of information is "BussinesDictionary.com" which has a specialization towards business terms. A guideline according to BussinesDictionary.com:

> Recommended practice that allows some discretion or leeway in its interpretation, implementation, or use.
>
> (*BusinessDictionary.com*, 2015).

How "BusinessDictionary.com" defines a guideline by saying it is a recommendation and that it is up to the engineer to decide if it should be followed. This definition makes another aspect of guidelines more clear, that following them is optional. Guidelines are also defined as being a recommended course of action which is similar to the first part of the definition from Longman Dictionary of Contemporary English (2009).

4.1.2 Uses of guidelines in technical literature

In the book "Concurrent Engineering", Syan and Menon use the term guidelines in the context of design for manufacture.

> Typically, the guidelines are stated as directives that act to both stimulate creativity and show the way to good design for manufacture. If correctly followed, they should result in a product that is inherently easier to manufacture.
>
> (Syan and Menon, 1994, p. 106).

Showing a way which should guide the engineer toward a good solution by providing examples of previous solutions which were well thought out and succeed to fulfill the goals can help in the design of a new solution. Syan and Menon also thinks that guidelines should be seen as 'optimal suggestions' which help to achieve a good product in terms of cost, quality and a design well suited for manufacturing.

Syan and Menon then explains that certain requirements may be in conflict the best solution according to the guidelines. Since requirements have to be followed, alternative solutions that are still good according to the guidelines should be chosen (Syan and Menon, 1994).

"Toyota Production System" by Y. Monden (1993) describes that a "Standard Operations Sheet", with a description of how to perform standardized operations, can be seen as a guideline for every workers' routine. In this context, the Standard Operations sheet is called a guideline even though its purpose is to describe how work shall be performed. A foreman should check that every worker follows the Standard Operations sheet and it is supposed to be updated at regular intervals when improved methods are found but the worker cannot change the operations on his/her own (Monden, 1993).

The guidelines for how to perform 5S are divided into main guidelines on a high abstraction level and each main guideline has its own sub-guidelines even though the sub-guidelines are not stated one by one, but rather intertwined in the text, covering different aspects towards the main guidelines (Monden, 1993). This section mixes tasks that must be done with general recommendations of aspects that should be considered.

> A common guideline states that around 75-80% of all use problems arise if 5-6 test subjects are included in the study.
>
> (Osvalder, Rose and Karlsson, 2009, p. 512).

In reference to usability testing, the word guideline is with the meaning as a "rule of thumb" in the chapter "methods" by Osvalder, Rose and Karlsson in the book "Work and technology on human terms" which is yet another interpretation or usage of the word guideline.

It is clear from these findings that anything close to a unified definition of the word guideline is not available and this leaves the interpretation at the discretion of every author. This is problematic since guidelines really have a role to fill, along with the terms in following sections. The previous uses of the word guideline can still form the basis for a definition of the word guideline by pointing out the general direction.

4.1.3 Standard guides

One last possible source of insight into the role of guidelines is connected to the term "standard guides" which aim to provide more insight into standards. Standard guides are used in order to make standards more clear and to support their usage. Guides give rules, orientation, advice or recommendations relating to international standardization and conformity assessment (Iec.ch, 2015). This means that guidelines could be kinds of instructions of how to interpret standards and how to make use of them.

4.2 Requirements

One term related to guideline is requirement. The main difference between them is that requirements must be followed while guidelines are optional to follow. The word requirement according to the Longman Dictionary of Contemporary English:

> something that must be done because of a law or rule
>
> (*Longman Dictionary of Contemporary English* 2009, p. 1483).

According to many sources in literature, time to market should be as short as possible to maximize the incomes of a product but according the book “Requirements Engineering” the objective should instead be “time to market with the right product” (Hull, Dick and Jackson, 2011, p. 1). This is a very good point since many companies want their new products to reach the market as fast as possible but that is not enough since it also has to be the right product which the customers want.

Hull, Dick and Jackson (2011) explain that the foundation of all projects are requirements and the difficulty lies in trying to describe a problem or need using clear and understandable language while keeping the description unambiguous and complete. It may be obvious why the language of a requirement must capture the wanted functionality or describe the problem correctly but this is only half the challenge, the other part is to make sure the readers and users of the requirement understand what is described and how to use that information.

Senior management can understand the development with a set of clear non-technical stakeholder requirements (Hull, Dick and Jackson, 2011). Thinking about the management is also very important since they make many of the decisions and the stakeholder requirements can then make sure those decisions are well informed and based on fact.

Unstable requirements may cause difficulties during development and lead to struggles (Hull, Dick and Jackson, 2011). As stated earlier, the requirements are very important for development and this means that bad requirements or change too much will have negative consequences. Having stable requirements of high quality is therefore essential. The main criteria from Hull (2006) for requirements of high quality are show in table 4.1 on page 28.

These criteria can be seen as what to fulfill at a minimum to make sure the requirements are of high quality and are of use. Hull, Dick and Jackson (2006) also state some more criteria for application to groups of requirements, see table 4.2 on page 28.

Hull, Dick and Jackson (2011) state that improper management of requirements has led to failure of many systems and in some cases has led to “user-less” systems, meaning the system may be functioning but not in a way the users want. This has

Table 4.1: Criteria for high quality requirements in Hull, Dick and Jackson (2005).

Criteria	Description
Atomic	Only one traceable part in every requirement.
Unique	Every requirement is possible to identify uniquely.
Feasible	Can be fulfilled within business targets.
Legal	Is permitted by law.
Clear	Is understood in a clear way.
Precise	Each requirement is short and to the point.
Verifiable	It is clear how to verify the requirement what to verify.
Abstract	The requirement does not force solutions.

Table 4.2: Criteria for groups of requirements (Hull, Dick and Jackson, 2005).

Criteria	Description
Complete	The needed collection of related requirements are available
Consistent	None of the requirements are incompatible with each other
Non-redundant	Nothing required is stated in more than one requirement
Modular	Requirements in a group are closely related
Structured	The documented requirements are structured in a simple way

also been described by Osvalder and Ulfvengren (2009), see section "4.6 Information system design". Having a system which functions as intended and having the system function in a way which fits the users is an issue which need high quality requirements.

Requirements also provide a way of communication, they can be used to understand what is happening at other levels and for comparing (Hull, Dick and Jackson, 2011). This is related to communication with management but the requirements can also provide an indication of progress status between departments. The requirements also make it clear for departments what they need from each other and how their works can fit together. For this, requirements must be updated and maintained (Hull, Dick and Jackson, 2011). In large businesses some kind requirements management system is needed to achieve the updating and maintenance of requirements. This may be true for other terms such as the previously mentioned guidelines and the following Key Performance Indicators.

4.3 Standards

Standards are intended for longer and more widespread use compared to requirements. Standards are also supervised and maintained by one or more organizations with the task of managing them. The definition of a standard according to Kresse, Danko and Fadaie:

> A standard is a documented agreement between a producer and a consumer, i. e., a reference document to be used in contracts and international trade which specifies definitions of characteristics, technical design or content, precise criteria, rules, or guidelines.
>
> (Kresse, Danko and Fadaie, 2012, p. 396)

It is evident even from the definition that standards are kept much stricter than requirements and one reason for that is that the standards are used between companies and organizations as a way to come to agreements more easily. Different types of standards have specific regions or user groups as focus areas, they range from company standards for use within a specific company to international standards which apply to all regions (Kresse, Danko and Fadaie, 2012). The amount of governance of a standard is dependent on the size and location of the user group.

Kresse, Danko and Fadaie also explain that there are two main types of standards: de facto which are prevailing in a market no matter if they are legal or not and de jure which are standards that are legal and managed by a nation or an organization (Kresse, Danko and Fadaie, 2012). Standards institutes are managing de jure standards which are clearer for companies to deal with and to use for business agreements since the legal issues are already solved and the thing left to do is to see if the standard lives up to the companies demands. The main benefits of standardization according to Kresse, Danko and Fadaie (2012):

- A big variety of applications can avoid the expenses related to adapting interfaces through the use of standardization.
- The work of writing laws are supported by standards.
- Companies can get ahead by being involved in the standardization work, compared to those not involved.
- A company can use many suppliers with the help of standards.

The standards institute ISO/IEC (2011) also mentions the concept of barriers of trade which means that the trade between many different parties is something which their standards aim to facilitate. Reducing the amount of issues which must be solved before trade can begin is something that ISO/IEC consider and try to handle in the best way possible.

Standards at a particular abstraction level usually only put demands on factor on the same abstraction level while leaving the other levels open all kinds of solutions (Kresse, Danko and Fadaie, 2012). This is somewhat similar to the way requirements are used since they should only describe what to fulfill and not how to do it, thereby not limiting creativity.

There is also the expressed objective to take future developments into account for documents published by ISO/IEC (2011). This can both motivate why solutions are limited to their abstraction level and why a standard cannot be so strict that it limits future developments.

4.4 Key Performance Indicators

Measurements of performance are very important for many businesses but what to measure and how to interpret is more difficult to know. By combining measures of performance, one can show high level business performance which are more relevant for business strategies (Slack, Chambers & Johnston, 2010). What to measure must be adapted to on what business level the measurement is to be used and for what decisions it will form the basis for.

Performance measures can be divided into Key Result Indicators (KRIs), Performance Indicators (PIs) and Key Performance Indicators (KPIs) (Parmenter, 2010). The main differences of these three indicators, according to Parmenter (2010), is the level of detail or abstraction level. KRIs are the on the highest level of indicators, PIs are medium level indicators and KPIs are the lowest level of the three and the most detailed (Parmenter, 2010).

KRIs are influenced by many actions, they show where things are heading and are therefore not providing information of how to improve the situation (Parmenter, 2010). This corresponds with KRIs being on the highest abstraction level where it is hard to relate the overall performance to specific courses of action.

BusinessDictionary.com defines KPIs in the following way:

> Key business statistics such as number of new orders, cash collection efficiency, and return on investment (ROI), which measure a firm's performance in critical areas. KPIs show the progress (or lack of it) toward realizing the firm's objectives or strategic plans by monitoring activities which (if not properly performed) would likely cause severe losses or outright failure.
>
> (*BusinessDictionary.com*, 2015b).

Parmenter (2010) lists seven main properties of KPIs:

1. Not a finance measure

2. Daily measures or more often

3. Input for CEO and senior management
4. All personnel must understand the measure and how to fix it
5. An individual or a team must be in charge if it
6. Having an important effect
7. Having a beneficial effect

KPIs indicate how critical success factors are being influenced by the organizations performance (Parmenter, 2010). By connecting the success factors with measurements from different parts of the organization and by indication where improvement is needed the resource spent can be reduced.

A good rule of thumb is to have around 10 KPIs (Parmenter, 2010). This means that there needs to be prioritization in order to keep the number of KPIs at a reasonable level but it also means what KPIs to use and measure must change when the organization evolves. The KPIs must therefore be updated continuously both in terms of the values but also what to measure.

Staron, Meding and Nilsson (2009) present a framework for measurement development which shows how to handle larger numbers of measurements with system support to assist managers.

> By using measurement systems the managers, can focus on a few key indicators (metrics with associated interpretations) instead of monitoring large number of metrics.
>
> (Staron, Meding & Nilsson, 2009, p. 721)

Staron, Meding and Nilsson (2009) continues by explaining what is needed in an organization in order to assist decision-making.

> As effective use of these measurement instruments in decision support processes requires combining the resulting values and presenting them as key indicators, measurement systems combine metric values, interpret them using pre-defined decision criteria and later present the indicators to the stakeholders.
>
> (Staron, Meding & Nilsson, 2009, p. 721)

4.5 Concurrent Engineering

There are many challenges for manufacturing companies and one especially competitive industry is the automotive industry. Quick changes in demands and customer needs are examples of challenges for car manufacturers. Syan and Menon (1994) illustrates this with an example from Rover who launched a model of “Land Rover

Discovery" after 18 months of development when competitors in Europe spent 48-63 months for similar products. The "Land Rover Discovery" model became a bestseller in its segment due being introduced so early to the market (Syan and Menon, 1994).

The manufacturing industry is becoming more and more aware that "time to market" is currently one of the most important competitive issues (Syan and Menon, 1994). There are many reasons for the time needed to introduce a product into market. Customers are increasingly demanding cheap, nicely designed, high quality products with lower and lower lead times (Syan and Menon, 1994). All of these demands are difficult to handle and they put a high pressure on the organization of a manufacturing company.

Between 60 to 95% of the costs related to the whole lifecycle of a product are determined during design, according to studies on the subject (Syan and Menon, 1994). The design phase is therefore important for costs but it is also important for how quickly a product can be introduced to market or a specific product's time to market. A very common method to achieve a short time to market, while remaining profitable, is Concurrent Engineering (CE) and it is widely used throughout industry (Syan and Menon, 1994).

CE is a way to work in parallel between departments instead of the more classical way of working sometimes called "Over the wall engineering". The name comes from the analogy of one person working with for example a blueprint and once finishing the work, throwing the blueprint over the wall to the person next in development and not caring about what happens next. The person receiving the blueprint is also left out of the previous step and cannot therefore give feedback to the design of things which may be problematic later on. Over the wall engineering has to following problems according to Syan and Menon (1994):

- Inadequately specified products, increasing the number of product modifications
- Manufacturability issues of products are not considered enough during the design phase
- Many design changes are made during later stages, leading to increased costs and bigger errors is cost estimates
- Costs for new equipment and tools are higher due to more late changes

CE puts high demands on many parts of organizations because of the radical changes compared to earlier common practices (Syan and Menon, 1994). This means that companies wanting to adopt CE will face a lot of challenges and it might also be unclear what exactly will be improved for a company adopting CE. Syan and Menon (1994) lists the main objectives when using CE:

- Shorter time to market with shorter product development

- Larger profits
- Better competitive position
- Lower costs for design and production
- Cooperation and integration of departments
- Better company reputation and more desirable products
- Better quality of products
- Improved team morale.

All of these objectives are things which should seem beneficial to most companies and CE should be seen as a way to achieve them. Syan and Menon (1994) gives the following summary of why CE is needed in order for companies to stay competitive:

> It is necessary to attack the causes of delay in the development process. As the products have a short lifetime, no time is allowed for the companies to correct design errors or re-engineer products to higher quality at low costs. Therefore it is essential to renounce a philosophy of 're-do until right', and introduce the philosophy of 'right first time'.
>
> (Syan and Menon, 1994, p. 10)

All delays affecting the so important time to market must be fixed and removed to stay competitive. Companies producing products which will have an advantage from a lower time to market will have an advantage of CE (Syan and Menon, 1994). This provides the motivation why companies should consider CE, especially automotive manufacturers who operate in a highly competitive market where time to market can have a big impact on profitability and on market position.

4.6 Information system design

One very important aspect of system design is to consider the users and to design the system with humans in mind. There are many things to take into account when designing for humans, both in terms of their abilities and in terms of their limitations. The system needs to be of use for the users, to provide some benefits or to have as high degree of usefulness as possible.

Usefulness for a system has two dimensions: utility, meaning that the system can perform what is required and usability, to what extent the user is able to use the functionality of the system (Osvalder and Ulfvengren, 2009). The first dimension of utility is something that is mainly considered, as evident by many real-world examples, while too often forgetting or at least to a less extent considering usability. A big part of the projects concerning content management systems are unsuccessful because of them not grasping the issue of usability, too much focus on technology and a lack of adequate implementation standards (Dalkir, 2011).

A well designed system can make use of the human abilities while also avoiding any influence of the imperfections and weaknesses of the human user (Osvalder and Ulfvengren, 2009). This means that many aspects of human nature must be considered to achieve a high degree of usability and to adapt the system design to the properties of human users.

4.6.1 Memory

Memory of humans is one of those aspects and short term memory will have the greatest effect on system usability since most of the actual handling and inputs in to the system will be kept in short term memory. Information in the short term memory is kept for about 30 seconds, unless it is repeated (Osvalder and Ulfvengren, 2009). This means that there is a lot of need for support of the short term memory and to rely on it as little as possible. About five to nine bits of information can be kept in short term memory at a time (Osvalder and Ulfvengren, 2009). Implications of this is then that bits of information should be kept in the designed system while only leaving things up to the short term memory when absolutely necessary.

One human property the affects the demands of the system is knowledge level, if the user is an expert or a novice will result in different demands. An expert can handle more concepts at a time, this is due to them keeping the bits of information more abstract than novices in their area (Osvalder and Ulfvengren, 2009). Experts understand the connections between concepts while concentrating less on the details. But because of this experts risk missing subtle details due to seeing the whole picture and not so many of the details (Osvalder and Ulfvengren, 2009). Seeing the forest while not seeing the trees can both be a good thing and a bad thing, depending on the context.

The effect of expert knowledge can be exemplified using the interface of a survey. How can the respondent of the survey know that only one option is allowed in figure 4.1 on page 35? For some users its clear only by looking at the buttons but with less experience it is not clear. If the respondent is told that the buttons are called radio buttons, will that help? No, not without the following background information.

Figure 4.2 on page 35 shows a radio from a Volvo car and the numbers from 1 to 6 are used to store radio stations. How many of those stored radio stations can you listen to at once? Easy right? One! If you listen to number one and then press number two, number one gets deselected and number two is selected. With this background connected to the buttons in the survey it is apparent what selections can be made.

Information kept in memory fit into networks connected by associations (Osvalder and Ulfvengren, 2009). These associations are different depending on experience and level of knowledge. Knowledge in memory will be lost if it is used too

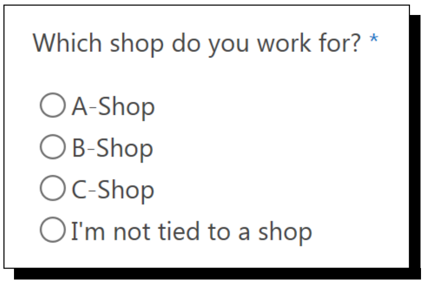


Figure 4.1: Usage of radio buttons for a question in a survey.

Figure 4.2: Radio buttons on a radio in an old Volvo V70.

rarely, regular use of the knowledge will reduce this risk (Osvalder and Ulfvengren, 2009). This needs to be considered when deciding to what extent to rely on the users' memory.

4.6.2 Decision-making

Working with large amounts of information and insufficient time will lead to a person taking shortcuts if the task is beyond his or her capability (Osvalder and Ulfvengren, 2009). Even in situations with less demands on time to solve the task it is still important to have a good balance of the amount of information that the user is expected to analyze, keep track of and decide upon. Users may use shortcuts when they make complicated decisions, this is called bias (Osvalder and Ulfvengren, 2009). It is then very important to provide an increased amount of support for the decision-making when the complexity rises in order to avoid the user taking shortcuts. Trends are a better way of assisting decision-making than large amounts of information (Osvalder and Ulfvengren, 2009).

Since the risk of the user taking shortcuts increases with larger amounts of information then possible solutions for this must be considered because the decision will be pointless or at least much less useful if they are the product of a user taking shortcuts. The usage of checklists with information of what consequences the decisions will have is another way of facilitating decision-making information (Osvalder and Ulfvengren, 2009). By having the user filling out checklists the amount of simultaneous information can be lowered and by reducing the possible choices to a few with clear consequences of the alternatives the user can be assisted to make informed decisions, even with larger amounts of information. Data onscreen should not require analysis if it is avoidable and kept to a minimum if is not (Osvalder and Ulfvengren, 2009).

One example of this could be to convert a limit on area (m^2) into limits on width and length in meters, if the maximum area is 5 m^2 and the width is 3 m what will the maximum allowed length be? What if the maximum area is 5 m^2 and the width is 6 m what is the maximum allowed length? These questions are not very easy to answer without a bit of thinking and with even more alternatives the risk of taking shortcuts increases even more. The answer to the first question is: 1.6666... and the answer to the second question is: 0.8333... If the limits are presented with cases where either the width or the length is fixed and the user only has to choose between alternatives and not perform any calculations then the decision will be much easier to make.

4.6.3 Content management

A very important aspect to consider when designing a system is how the information or content in it should be stored. Content management, storage and structuring all need to be handled in a standardized way (Dalkir, 2011). Standardization is needed to facilitate interaction and integration of different systems and if data transfer is done according to a standard it will be easier to use many systems without first tailoring outputs and inputs.

Archiving, tagging and classification are important parts of content management (Dalkir, 2011). This is due to the fact that it is not enough to have the information stored in the system but it must also be possible to find relevant information with as little effort as possible. Metadata such as: keywords, notes, authors and dates all help with content management and provide information about the related content (Dalkir, 2011). Much more efficient filtering is possible with the help of metadata because information can fit into many contexts. A specific meeting room can just be one in a list of possible rooms to use but the same room can be on the highest level when finding out how much a specific room gets used.

Information in a tree structure, or “taxonomies”, can help with the problem of organizations having different terms and language used in different parts within the organization by sorting them in a hierarchical structure (Dalkir, 2011). By sorting information with the help of hierarchies both filtering and presentation of data can be made to fit the preferences and requirements of many departments within a company. Technology and developments move away from company portals towards content tailored for each user and their specific needs (Dalkir, 2011). With developments of more advanced IT solutions, more and more information is available and that increases the need for better and more intelligent ways of filtering and presenting information.

4.6.4 Wikis

One way to add a more personalized knowledge management is through the use of Wikis (Dalkir, 2011). Knowledge management on a personalized level is one step further than the tailoring towards departments. Open editing of a website with many users writing and editing content is called a "Wiki" (Dalkir, 2011). The most famous wiki is "Wikipedia" but this kind of solution is available in many other places. By giving users and authors a lot of freedom it is possible to facilitate a quicker workflow while letting people, who might not be comfortable with the responsibilities that come with writing something which later will be published, contribute. The currently common alternative when finding some text where information missing and contacting the owner via email with a suggestion. With wikis, it is possible to instantly edit and add what is missing in a text stored in the wiki.

Wikis can secure access to updates documentation compared to copies in group emails (Dalkir, 2011). Communication through emails usually have the drawback of a lot of waiting and instead of trying to figure out which of all emails have the latest version it is much easier to always go to the wiki. Wikis can facilitate monitoring of progress and issues without direct involvement (Dalkir, 2011). This can then give more insight into development phases that have previously been hard to assess where it might seem nothing has happened in terms of development.

4.6.5 Interface and Layout design for humans

A user interface is the only way a user can connect to and interact with a system, this puts high demand on the way a user interface is designed (Osvalder and Ulfvengren, 2009). There are of course many aspects of interface design but it does not matter how nice an interface looks if the user cannot use it and this means that usability is the most important aspect of user interface design. There is a risk of users feeling disconnected from a system the more advanced they get (Osvalder and Ulfvengren, 2009).

Having an understanding of how the system works in basic terms, knowing what role it has and what its purpose is can help to reduce this feeling of disconnection. High usability can only be accomplished if the designer of a system knows what data should be presented and how to do it (Osvalder and Ulfvengren, 2009). It is not as easy to just show all data, instead there needs to be a method to sort out what data will help the user while hiding all other information. How this relevant information is then shown should also be aimed towards helping the user to make sense of the data and to assist decision-making.

Specific information should have its own place in the design, avoid moving it around (Osvalder and Ulfvengren, 2009). By having a consistent design and preferably in a way that users are already familiar with the users will spend less time looking for the relevant information and the risk of missing important elements will be reduced. Information with common elements should be grouped together (Osvalder and Ulfvengren, 2009). Grouping information in an intuitive way can also help the user to find what he or she is looking for. Using standardized designs can help when introducing changes (Osvalder and Ulfvengren, 2009). This can apply both to changes based on input from the user but also changes of the system's design when it is developed further to avoid users finding new designs problematic or less useful than the old design.

The users should find it easy to find out what functionality is available in the system (Osvalder and Ulfvengren, 2009). There is no point of having many fancy functions in a system if the user does not know they exist or cannot figure out how to use them. This is a very important aspect when designing a user-friendly system and if it can be solved without a lot of instructions or introduction then the system will have an even higher degree of usability.

4.7 System testing

Because the issue of usability for a system is so important, testing needs to be performed to assess usability and to come up with improvements to the system to increase its usability. Using methods for interaction analysis during system design can improve usability (Osvalder, Rose and Karlsson 2009). How users interact with the system needs to be analyzed thoroughly to improve this interaction and to make it suitable for as many user groups as possible. Redesign of the system can fix many of the problems related to usability (Osvalder, Rose and Karlsson 2009). But in order to know what to redesign and how it should be changed to improve usability, an assessment of what issues are currently present must be found out. Interaction analysis is not a foolproof process but all discovered issues should be addressed (Osvalder, Rose and Karlsson 2009). So while it will not be possible to detect all issues, the ones discovered need to be analyzed and solutions formulated. How well and thorough this work is done will of course have big impact on the quality of the results.

4.7.1 Hierarchical Task Analysis

Hierarchical Task Analysis (HTA) consists of dividing a task into sub tasks based on a hierarchical structure (Osvalder, Rose and Karlsson 2009). A very simple example of dividing the task of refueling a car with HTA is shown in table 4.3

Table 4.3: HTA analysis of refueling a car, based on Osvalder, Rose and Karlsson (2009).

0	**Refueling a car.**
1	Select pump.
1.1	Find unoccupied fuel pump.
1.2	Drive up to chosen pump.
2	Pay for fuel.
2.1	Go to pay terminal.
2.2	Insert credit card.
2.3	Enter PIN.
2.4	Enter pump number.
2.5	Take credit card.
3	Fill fuel.
3.1	Open fuel tank cover.
3.2	Remove fuel cap.
3.3	Select correct pump handle by looking what fuel they have.
3.4	Attach pump handle to fuel inlet.
3.5	Press and lock trigger to begin pumping of fuel.
3.6	Wait until the tank is full.
3.7	Remove handle from fuel inlet.
3.8	Replace handle on fuel pump.
3.9	Replace fuel cap.
3.10	Close fuel tank cover.
4	Finish refueling.
4.1	Get behind the steering wheel and start the car.
4.2	**Drive away.**

on page 39. This method will serve as the starting point for the other methods explained in detail below.

4.7.2 Cognitive Walkthrough

Two methods which can be used to detect usability issues will the discussed in this chapter: Cognitive Walkthrough (CW) and Predictive Human Error Analysis

Table 4.4: Task description for starting a car with a keyless ignition system, based on Osvalder, Rose and Karlsson (2009).

User:	Driver
Surroundings:	New car with keyless ignition system
Task:	Starting a car with keyless ignition system for the first time

(PHEA). CW and PHEA can be used to test out usability during system design while the detected issues can be addressed (Osvalder, Rose and Karlsson 2009). This means that both methods will be very useful during the system design phase, including the early stage where it is much easier to make drastic changes and where many other methods cannot be used due to it being so early in the development. Possible users, what functionality and the purpose are all part of the first stage when using CW and PHEA (Osvalder, Rose and Karlsson 2009). The functionality comes from the HTA analysis which together with user groups and the purpose serve as the starting points for both CW and PHEA.

CW will try to find out if the users will behave as intended and if not, why did they not behave as intended (Osvalder, Rose and Karlsson 2009). Information about if users will do the right thing and also if they do not is important to know how the system can be improved and these issues fixed. All tasks are performed in the correct order by the investigator during the CW analysis while considering the following four questions for each task with yes or no answers (Osvalder, Rose and Karlsson 2009):

1. Does the user attempt to make the right choice?
2. Is the right choice clear enough to be discovered by the user when it is accessible?
3. Is the right choice connected with the wanted operation by the user?
4. Can the user notice the progression if the right choice is made?

Based on Osvalder, Rose and Karlsson (2009).

An explanation of why the error occurred is given for every question which is answered with no (Osvalder, Rose and Karlsson 2009). An example of a CW analysis for starting a car with a keyless ignition system is shown in table 4.4 and 4.5.

CW is a cheap method to analyze both novice and experienced user behaviors but it might be time-consuming depending on the number of stages (Osvalder, Rose

Table 4.5: CW analysis of starting a car with a keyless ignition system, based on Osvalder, Rose and Karlsson (2009).

1. Start car	**Response**	**Problem**
Does the user attempt to make the right choice?	NO, the driver does not understand that car is started without putting the key in the ignition	How this car is started is different from the way the driver is used to
Is the right choice clear enough to be discovered by the user when it is accessible?	YES, there is button with the marking “engine start”	
Is the right choice connected with the wanted operation by the user?	NO, the user cannot find the start button	The button is placed somewhere different from the standard place on the steering column
Can the user notice the progression if the right choice is made?	YES, the car starts	

and Karlsson 2009). Due to the amount of time needed, which is very dependent on the amount of tasks, one needs to include what is the most important while keeping the analysis manageable.

4.7.3 Predictive Human Error Analysis

A PHEA analysis is centered on finding out what mistakes the user might make and what consequences the mistakes might lead to (Osvalder, Rose and Karlsson 2009). The mistake will have to provide the basis of improvements to the system and by including the consequences it will be much easier to prioritize the changes in terms of severity and urgency. All potential mistakes should be identified for each task or step (Osvalder, Rose and Karlsson 2009). This is to list all possible things that can go wrong for the user when interacting with the system. The following questions will need to be answered for each potential mistake (Osvalder, Rose and Karlsson 2009):

1. Why did the mistake occur?
2. What are the consequences of the mistake?
3. Can the user identify the mistake?

4. Can the user correct the mistake, how can this be done?

   Based on Osvalder, Rose and Karlsson (2009).

Some of the mistakes which have been identified during the PHEA analysis might not occur during actual usage of the system (Osvalder, Rose and Karlsson 2009). It is important to know that just because a mistake was discovered, it does not mean it will happen during usage and this aspect should be considered for every task when performing the PHEA analysis. Also PHEA, can be used during early stages of system design (Osvalder, Rose and Karlsson 2009). Which make this a second tool to consider when testing out early prototypes of a system.

4.7.4 Usability testing

Testing with users interacting with the system is called a "user test" and the participants should match the intended user groups as well as possible (Osvalder, Rose and Karlsson 2009). This can be challenging to form a group of testers who match the actual user groups as well as possible while trying to keep the number of participants at a manageable level. Problems found during a user test will have a high likelihood of also occurring during actual use (Osvalder, Rose and Karlsson 2009). The user test will then provide a better view of usability issues that will arise during actual use of the system. Satisfaction, efficiency and number of completed tasks are evaluated, first time usage and time to learn may also be evaluated during the user test (Osvalder, Rose and Karlsson 2009).

The test should last 30 minutes at the longest with 5 to 7 prearranged tasks, introduction and debriefing can be added to this time (Osvalder, Rose and Karlsson 2009). This might prove challenging to test out all the wanted functionality while reducing it to a maximum of 7 tasks and using no more than 30 minutes for the actual test. Some of this can be addressed during the introduction but you also do not want to help the user too much since this will not be the case in the real world use later on. The user tests are time-consuming but they provide much more valuable data on user behavior (Osvalder, Rose and Karlsson 2009).

"A common guideline states that around 75-80% of all use problems arise if 5-6 test subjects are included in the study" (Osvalder, Rose and Karlsson, 2009, p. 512). This quote provides a good rule of thumb of how many test subjects to include and as discussed in the section about guidelines; the word guideline is used in the context: rule of thumb.

Osvalder, Rose and Karlsson (2009) divides user tests into three parts: preparation, implementation and analysis. Preparation is very important since it will serve as the foundation of the user test and extra effort spent on this part will probably increase the chances of useful results. How the actual test is implemented, as described earlier, will also affect the outcomes and the usefulness of the results. The analysis part will of course be served by putting extra effort into the previous two steps, but it is also very important to extract results which can help to improve the system design.

Preparation is started by deciding what data will be gathered and what the target of study is, the sample of user groups must also be well thought out when choosing participants (Osvalder, Rose and Karlsson 2009). The first implication of this step is the need for time which will be affected by both the amount of data to be gathered and the number of participants. Some amount of time will also have to be spent on choosing the right participants to get as fair sample of the future user groups as possible. What specific data to collect should also be chosen carefully to test out what improvements are needed while keeping in mind the time used for the user test and the time needed to do a proper analysis of the results.

Implementation begins with selecting the tasks and the order to perform them, all participants should be treated the same and be informed that their own ability is not being tested, but rather the system design (Osvalder, Rose and Karlsson 2009). The tasks to include in the test need to be areas where problems are likely to arise but the bigger consequences a mistake will have, the more important it is to include that task. Informing the users about the purpose to test the system and not the participant's skills is also very important. The more the consistent the users in the test are treated, the lower the risk of skewed results will be.

Analysis is made much easier with well thought out and planned tests but this is related to the amount of data gathered (Osvalder, Rose and Karlsson 2009). During the analysis phase you can really reap the rewards from performing the previous steps well and spending time on preparations.

5

Results

RESULTS will present the main findings from this master thesis which are the continuation of what was found in the chapter "2 Current state". It is for that reason recommended to read Current state before reading this chapter to get the necessary background. Results will first cover "Bad guidelines" which aims to explain the differences between good guidelines and bad ones. Some possible reasons for bad guidelines will also be covered to find ways to avoid bad guidelines in the future. "5.2 Survey about guidelines" will then cover a survey about guidelines and their place at VCG. The section after called "5.3 Defining a guideline" describes the work performed to come up with a suitable definition of a guideline. "5.5 Case study applications" contains some attempts to apply the definition and criteria to both existing guidelines and existing requirements. Finally, "5.7 MEGMAS design" will present how the high level system functionalities were selected to come up with a suitable system for managing guidelines.

5.1 Bad guidelines

One very central thing of a guideline according to many of the persons interviewed at VCG is that it must add value or be useful. If the guideline is not useful it will not only fail to provide an engineer with guidance about an issue, it will also take up space in a collection of guidelines. The one useless or simply put, bad guideline, might not pose a very big problem. A very large collection of guidelines with many bad ones will however pose a problem since the engineers are expected to consider all relevant guidelines when designing production solutions. The aspect of relevance is another issue which becomes more important to address the larger the collection of guidelines gets.

It can then be stated that all guidelines which do not help the engineers considering or using them are bad. The central thing is not for a guideline to be of clear to the author, but to be clear to the audience or users. Guidelines found at VCG had a broad spectrum in terms of clarity and quality. Some were found to be perfectly adequate while others were more unclear and less fit for use. One explanation for this might be the different views on guidelines and their purpose. But the view that some of the guidelines are bad comes from two people from the outside of VCG. A sample of guidelines of varying quality are analyzed in the coming section (5.2 Survey about guidelines) about the survey at VCG.

Some possible reasons of why it is bad from the view from someone unfamiliar with ME (the author of this report) is shown in figure 5.1 on page 47. The main example analyzed is the guideline “Optimized main flow is secured” but the reasons were found to apply to many of the guidelines. As shown later in this chapter (under 5.2 Survey about guidelines), the aforementioned guideline is not bad according to everyone with knowledge of guidelines within VCG and the same is true for many other guidelines.

There may of course be more explanations of why a guideline is bad but this study found two main areas of explanations: an unclear role for guidelines and explanations related to the author being an expert writing with only other experts in mind. The unclear role of guidelines which was first mentioned in 2.1 Guidelines where company documents at VCG were analyzed to find the different uses of guidelines.

Unclear role for guidelines

If an author gets the task to write a guideline then the task must be made clear, otherwise the quality of the guideline will suffer. This includes the need for a clear goal and a clear purpose for the written guideline. It is necessary to know who will read the guideline, what they will use it for and what their levels of knowledge are. Very fundamental is also exactly what a guideline is. If a guideline is written for one purpose and the same guideline is used in a different context there is a risk of problems related to the guideline being out of context. If the author is given the task to write a guideline for a specific abstraction level and at the same time being asked to write a guideline about an issue which should belong to another abstraction level there is a risk of problems. One example of this could be: “Make sure visual indicators can be seen by the operator” on the station abstraction level. The problem in this example is that the design of the station is only part of ensuring a clear line of sight since another station might still block the line of sight. Therefore, the guideline should be considered at a higher abstraction level, at area level for example. Some guidelines may make sense at many different abstraction level but some do not.

Expert author

Even though it might be easy to blame the author of doing a bad job, it is hard to see that such an explanation would be a fair assessment in more than a very

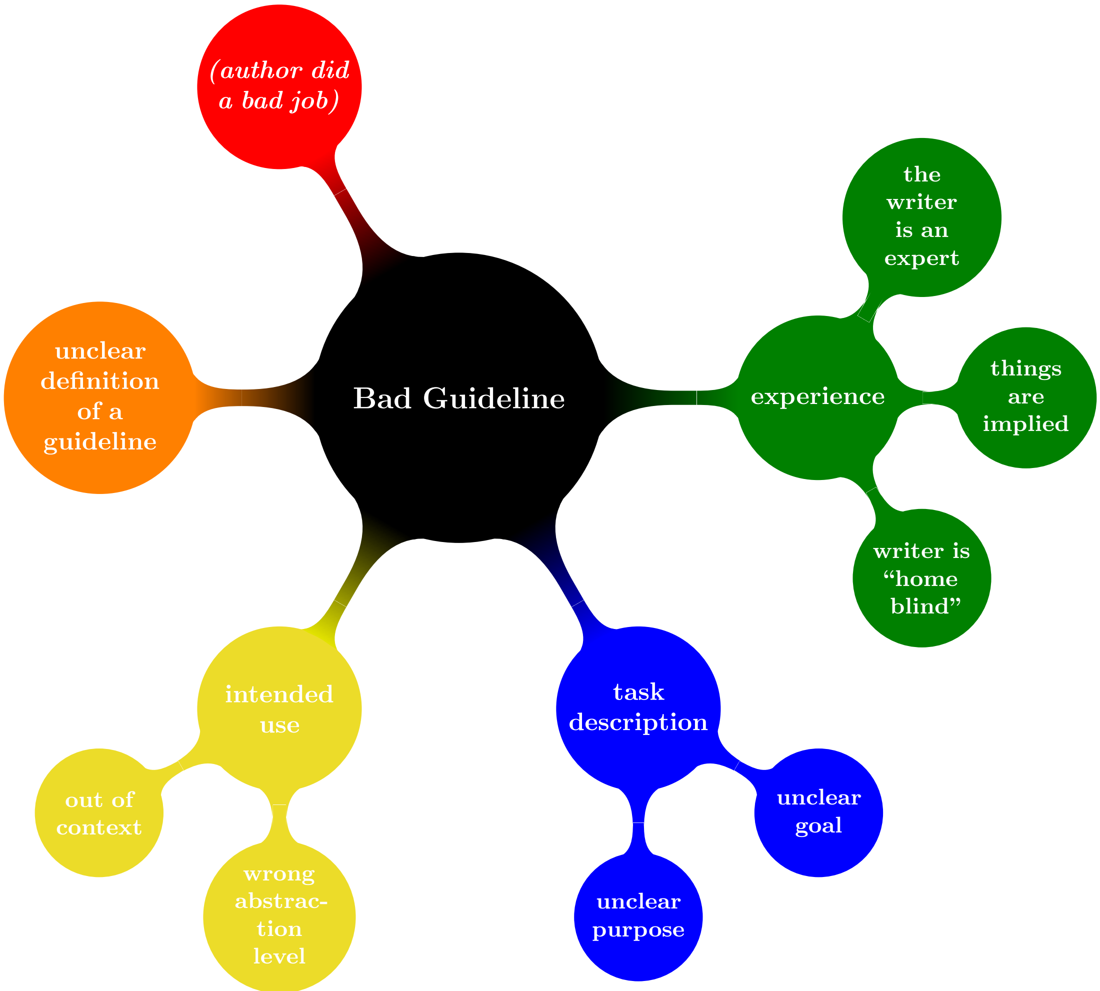


Figure 5.1: Possible reasons for a bad guideline, according to the author of this report.

limited number of cases. None of the examples at VCG showed any sign of this. Instead there were issues related to the author being an expert and writing for other experts. As shown in the theory section: experts tend to leave things implied or filling in the blanks. A home blind expert will leave even more things implied since they were too basic to include, even though this might not be true for a novice reader or a reader will less experience.

5.1.1 The need for a survey

From the analysis of a sample of guidelines there was wish to verify if the guidelines needed improvement which was assumed. If some of the guidelines need to be improved, one must know what to improve. This kind of input can be one part of what to improve which can be combined with other sources and ideas to maybe make the guidelines better than the users of them can imagine. Other parts of the survey is to get to know the future users of the guidelines and the MEGMAS, mainly to find out what kind of information should be kept in it.

The aforementioned issues and explanations had to be verified with personnel at VCG who have considerably more experience and knowledge. This was also at an early time when there was a lot of unfamiliar territory concerning guidelines and VCG as a company. There was also a hope to verify the theories presented above.

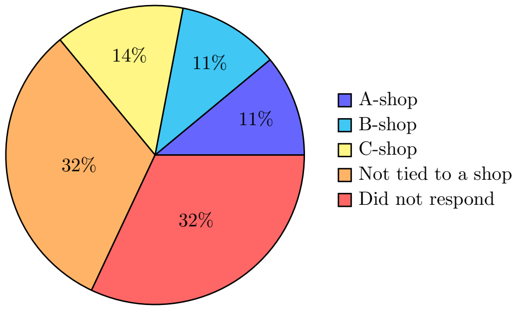
5.2 Survey about guidelines

A survey about guidelines at VCG was made to try to clarify the role and purpose of guidelines. As explained in the chapter “3 Methodology” a survey is useful to gather a lot of data in a short amount of time which fit well in this situation.There was a goal of making sure enough opinions from the three main factory departments (Body, A-shop; Paint, B-shop; Final assembly, C-shop) were collected since they have somewhat different points of view. Contributions and resulting data from the departments within ME are shown in figure 5.2a on page 49.Two optional questions concerning work experience of the participants were added, mainly to point out the vast experience of the people who contributed to this master thesis. See figure 5.3a on page 49 and figure 5.3b on page 49. It is clear from these results that the people at the ME department have lots of experience to deal with challenges of planning the production at VCG.

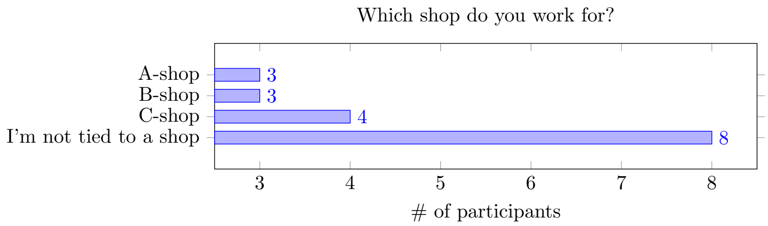
The complete number of participants from the three shops and other participants from ME are shown in figure 5.2b on page 49. 28 people were asked to participate, nine of them did not respond to the survey. Eight people of the nine were from outside the three shops which means the was a very good response rate from the shops with only one person choosing to not participate. The number of eight people not participating (outside the shops) is fairly high but the main target for the survey was the shops since they are the intended users of the MEGMAS. Getting views and understanding possibilities for guidelines was the main reason to include people outside the three shops.

Next, the survey asked about the properties of guidelines where the respondents were asked to choose one or more properties (see table 5.1 on page 50). What possible purpose or purposes a guideline has was then asked to get input to a description of the roles of guidelines, see table A.4 on page 95. As a way of finding out where guidelines are used during development and possibly production the participants were asked what sources guidelines may have (table A.5 on page 96).

Possible abstraction levels for product and process respectively are shown in table A.6 on page 97 and in table A.7 on page 98.

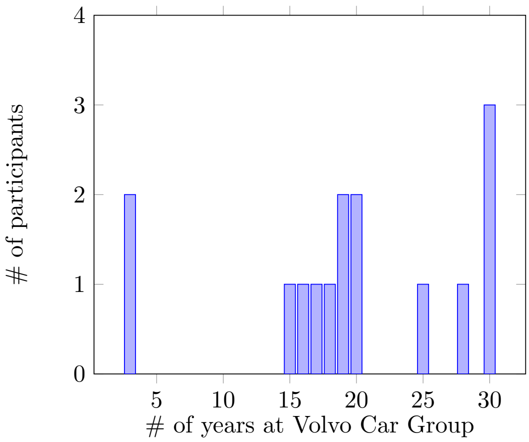


(a) Distribution of participants in the first survey.

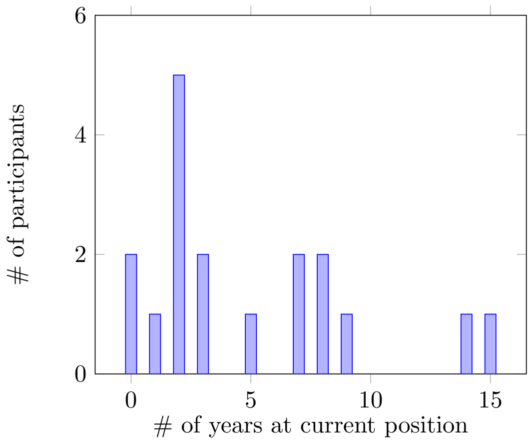


(b) Number of participants from the shops and outside the shops.

Figure 5.2: Participants of the survey



(a) Time at Volvo Car Group of respondents to the survey.



(b) Time at current position of respondents to the survey.

Figure 5.3: Work experience

5.2.1 Quality of specific guidelines

While studying guidelines at ME related to layout work, some examples stood out as extra interesting. The participants were asked to rate these to see if they agreed with each other and if they agreed with the two students. First, some general guidelines (apply to all shops) were rated, see figure 5.4 on page 51 and figure 5.5 on page 51. For more examples see "A.1 Survey" in the Appendix. The examples included in this section aim to highlight the somewhat varying quality of the guidelines included in the survey but also that the opinions of what a good guideline vary as well.

5.2.2 Guidelines related to specific shops

One interesting example of a guidelines which were written with a specific shop was rated as well (figure 5.6 on page 52). For more examples see "A.1 Survey" in the Appendix. Some of these guidelines which apply to specific shops may include concepts specific to that shop but they should still be clear enough to be understood by everyone at ME. The survey was made to make sure people outside the shops got to rate the shop specific guidelines for just that reason.

Table 5.1: Properties of guidelines according to the survey.

Property	**# of answers**
Guidelines provide knowledge support following best practices or avoiding problematic situations (warnings).	16
Guidelines are instructions supporting decision making.	9
Guidelines provide knowledge support forming an opinion toward an aspect.	5
A quick help/list to prevent risks in daily work.	1
I do not know.	0

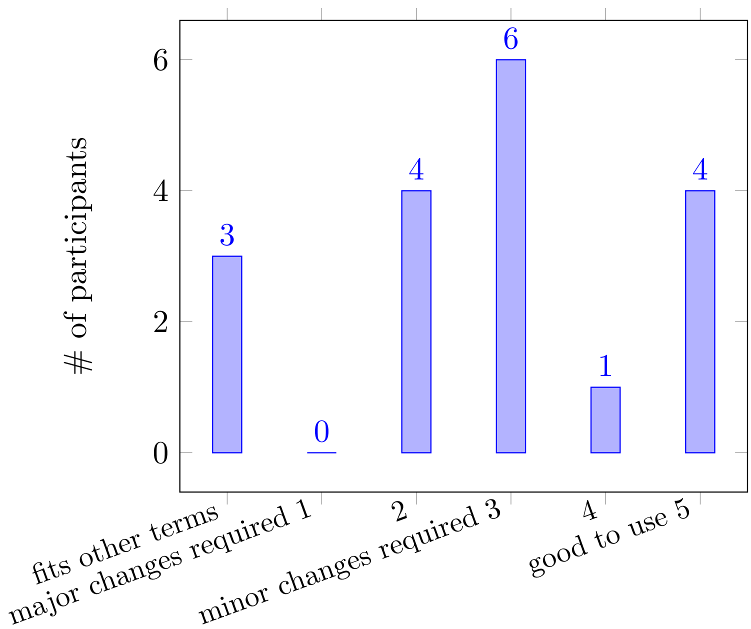


Figure 5.4: Guideline: "Visualization of the flow is secured".

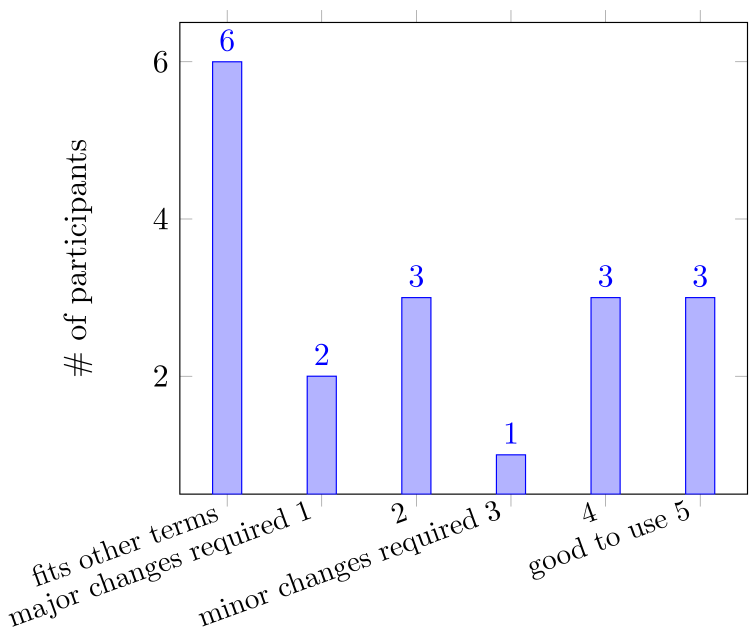


Figure 5.5: Guideline: "Every process must ensure a Safe and Healthy working environment".

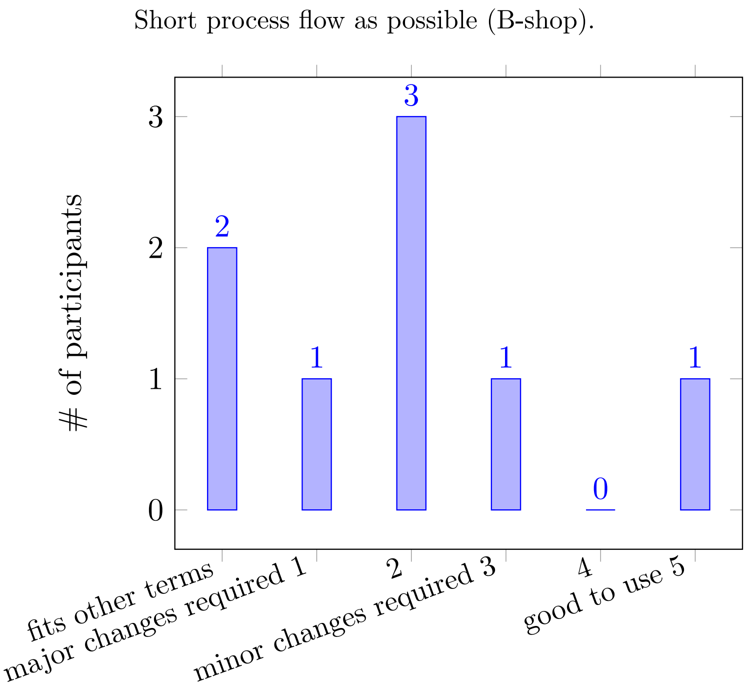


Figure 5.6: Guideline: "Short process flow as possible" (from B-shop).

5.3 Defining a guideline

One important aspect which needed to be analyzed as a prerequisite of the MEG-MAS was a clear definition of "guideline" with support from VCG, mainly from the ME department. This was partly due to the somewhat inconsistent use of "guideline" within VCG but also many uses of "guideline" in literature. A plan was formulated to include literature, VCG company documents and results from the survey at VCG. The input from these sources had a big variation in information which could possibly be a part of the definition. In order to make sense of this large amount of input, the following work was conducted.

A look through the literature from the theory point of view was conducted to extract everything which possibly could be part of a definition without removing things which would probably not make sense in a definition (table 5.2 on page 54). This was to attempt to minimize any bias towards what the current opinion of what a guideline is and to come up what a guideline could be.

The company documents from the (Business Management System) BMS at VCG related to guidelines were checked for input to a definition, all possible input was included without prejudice about the content (table 5.2 on page 54). A search function in the BMS was used to search for related documents. There is a category or document type called "guideline" which simplified the search. This showed all kinds of guidelines within many areas and departments of VCG. Guidelines related to manufacturing served as the main source but other guidelines were also checked to get an idea how guidelines are used at VCG and to get input towards a definition.

Every response to the survey was analyzed thoroughly to find what terms and uses from the answers could serve as input for the definition (table 5.2 on page 54). The survey asked questions about roles and uses for guidelines and the participants were asked to judge specific guidelines. This was done to understand what was problematic about some of the guidelines and what could be done to improve them. The possible improvements were then turned into criteria which if fulfilled, would improve guidelines and at the same time, avoid making the same mistakes. A tool could then be based on these results to support future work with guidelines.

The work towards the actual definition started with writing down all possible parts towards a definition of a guideline from: literature, company documents and results from the survey on post-it-notes with one color for each source. Notes with purposes were written with the same division of color and put in their own place. The notes were then sorted according to its origin (color) in to a 4x4 matrix formation (figure 5.7 on page 55).

Groups were then formed to contain related aspects while considering what aspects were found in all three sources which indicated importance, see figure 5.8 on page 55. This is where the colors served the purpose to indicate consensus between two or even three sources which was interpreted as importance.

Groups with outlier notes which did not make sense for a definition, such as, "something", "regulation" and "requirement" were removed. This was due to conflicts

Table 5.2: Considered input for the definition of a guideline.

Literature	Company documents	Survey
Not Mandatory	Lessons Learned	Best practice
Instructions	Tutorials & instructions	List of risks
Principles	Handbook	Avoid problematic situation
Clarification	Illustrated example	Opinion forming
Rule of thumb	Clarification	Support decision making
Support for terms	Expert knowledge	Best practice
A course of action	Visual clarifications	Support following rule of thumb
General rules	Standards	Decision-making support
Work instruction	Requirements	Support knowledge gathering
Orientation	Criteria	Instruction
Piece of advice	Regulations	Quick help
Stimulate creativity	Desired course of action	Support for terms
Possible future consequences	Support for terms	Checklist
Best way to do something	Manuals	Warnings
Avoid problems	Checklist	Knowledge support
Recommendation	Document type	Remarks
Guide	Condition	
Something	Remarks	
Indication	Form of knowledge transfer	
Guide towards best practice	Comment	
Optimal suggestion	Tips	
Checklist	Solution	
Form an opinion	Answer: What? Why? How?	
	Good design	
	Promote standardization (clarity & conformity)	
	Problem solving example	

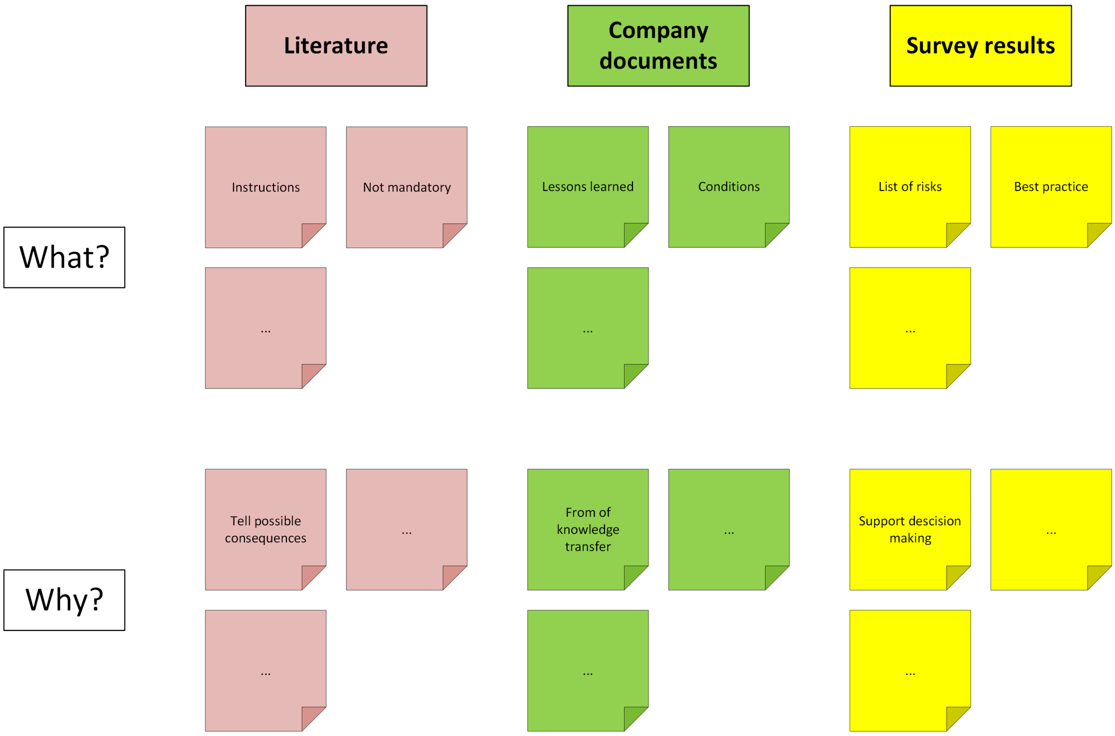


Figure 5.7: Sorting the input towards a definition and criteria

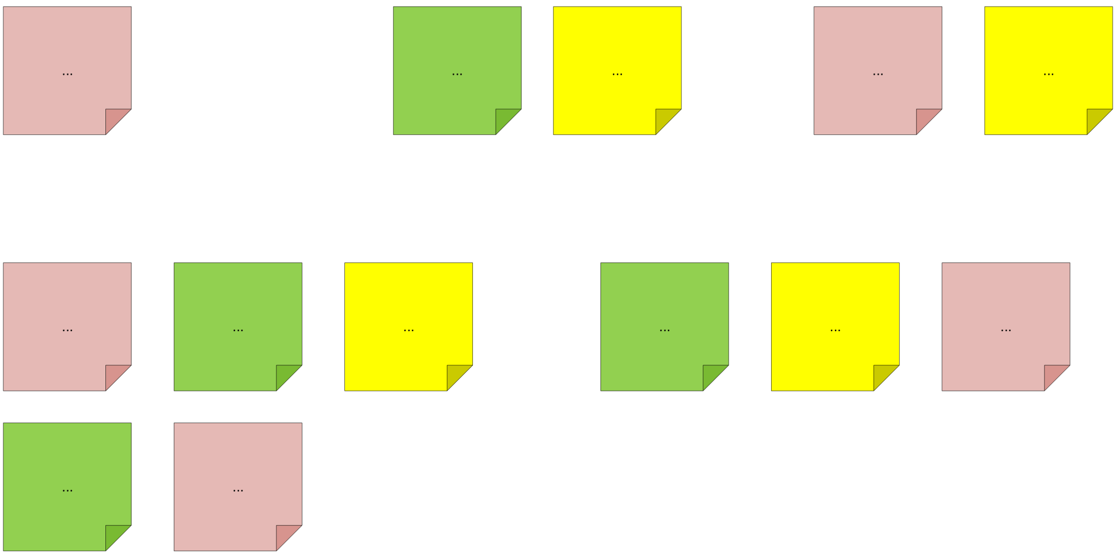


Figure 5.8: Grouping the input towards a definition and criteria

with other terms or aspects and some terms just added confusion. The groups were sorted according to importance which was indicated by their sizes and the number of terms in them with consensus from multiple sources. Terms with an appropriate amount of strictness were then selected while discarding the closely related terms since and definition cannot be too strict or too “fuzzy”.

The selected terms were then moved around to turn them into a sentence which made sense while still capturing all the notes. Notes with possible purposes for guidelines were sorted and those already captured in the sentence were removed. The notes left were worked into the sentence to capture the last information concerning purpose for a guideline. The wording of the sentence was changed around to try to achieve as high readability as possible, the final notes for the definition are shown in figure 5.9 on page 56.

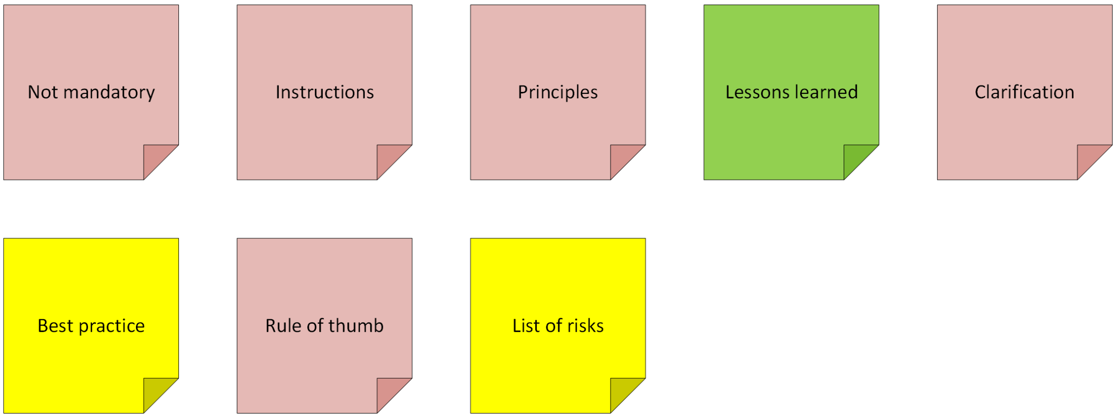


Figure 5.9: The selected terms for the definition

Feedback from the supervisor at VCG, Sten Gedda, was added and implemented in the definition of a guideline. Sten brought experience and extensive company knowledge, to help with the adaptation towards VCG and to make sure that the definition was suitable for use.

A mind map was then made to come up with criteria for guidelines to support the definition and to list what is needed to have a good guideline. All possible criteria were listed in the mind map, including possible explanations to “bad” guidelines found when researching the current state.

The criteria already supported by the definition were discarded and the criteria that did not make sense were removed. This list of criteria was sorted and explanations needed for clarification of each criterion was written. Some examples of guidelines were added to clarify what the aspects meant.

A first meeting was held with core representatives from the departments related to production and other people from ME to make sure the definition was on the right track. The criteria, which had been sent out in advance together with the definition, was gone through one after one. A discussion was held for each item which was unclear and this resulted in improved criteria. The definition was deemed fit for use.

5.3.1 Trade-offs when writing a definition

The definition of a guideline needs to have some level of strictness to make sure the guidelines contain clear and usable information. There is however a problem when there is no agreement of what a guideline is and that is true both in literature and at VCG. It makes it very hard to write a good guideline when you do not know what is supposed to be in it and the same goes for a guidelines management system. When you build a system you must know what it is for and what information it should contain.

A guideline must be defined in such a way that it is not used as a term where all kinds of information can be put but rather information which is of real use and can fulfill the role of guiding the reader. This must be achieved while having agreement from both users and authors of guidelines. The issue of usefulness was something which caused the DGM to be almost unused and led to them being unknown by the participants in the survey.

The definition also needed to have a suitable length while trying to capture the must important aspects of a guideline and this meant that the definition had to be accompanied by some criteria to capture the whole role of guidelines.

5.3.2 Definition of a guideline

The definition of a guideline, in collaboration with Hafez Shurrab (Shurrab, 2015) is as follows:

"Guidelines are optional instructions derived from principles, rules of thumb, best practices and lessons learned to help forming an opinion and support decision making concerning a course of action and associated potential risks."

5.3.3 Criteria for a usable guideline

The criteria for a usable guideline, in collaboration with Hafez Shurrab are shown in table 5.3 on page 57.

Table 5.3: Criteria for a usable guideline, by Anders Samuelsson and Hafez Shurrab.

Criterion	**Description**
Optional	The guideline is optional to follow, if not, it is not a guideline. This does not mean that considering the guideline is optional and non-adherence may have consequences.
Instructional	Support users with instructions and general rules to guide their actions (direct or indirect commands or orders). <u>Task oriented</u>

	Describes tasks and possible prerequisites. Before you consider cycle time, you need to find out... Quantifiable Some guidelines need quantification (such as numbers) in order to make sense and be useful, rules of thumb often benefit from quantification. “Minimum 3.6 meter height in all aisles” “Pre-trim: 30JPH 2 lines” Example of instructional: Align the team with customer and process orientation.
Fact based	Good guidelines are derived from rules of thumb, best practices, lessons learned and principles. Therefore, they are based on facts or experience but not on guesses and common sense. Referable Recommended to have the background documented. Controllable The guideline must have an owner, approver, responsible department and a person responsible for controlling it when applicable.
Contextual	A guideline should belong to a group of guidelines that have share a common goal DGM are categorized into 6 main knowledge areas, each area has a group of aspects. A good guideline then should be related and included to the list that revolves around its corresponding aspect. Leveled Guidelines should helping forming an opinion and making a decision that belongs to the right abstraction level. Leveled guidelines to high business level: • Optimize production system capacity • Secure efficient logistics operations • Maintain satisfactory work environment Directed to audience Should focus on particular audience segment. Consider language and terms.

	Illustrated Pictures and other types of illustrations helps the reader to "see the reality" in a way that is very hard to accomplish with only text.
Scenario connected	Help forming alternatives to assist decisions. example: Assign a number of people that is suitable for the level of automation. The higher the level of automation is, the less space is needed for people flow.
Up-to-date	Good guidelines should be valid and not obsolete knowledge in relation to the current situation.
Non-contradictory	You cannot have a guideline which is conflict with a standard or requirement since those have to be followed while the guidelines does not.
Promoting conformity	The guideline must have the form to make sure following it leads to a solution which is aligned with the conformity and standardization of other solutions.

5.4 Analysis of the guidelines definition

The word optional used in the definition of a guideline has some risk of giving a reader the wrong impression. Optional in this context means that each guidelines does not come with a demand to be fulfilled. However, this does not mean that the guidelines does not need to be considered. The guidelines must be considered and each unfulfilled guideline will add some of risk.

Having lessons learned in the definition can be seen as something too specific for a general definition, especially if it is to be used in literature. But, if the meaning is seen as one input for a guideline is the lesson from a previous problem in general and not the framework "lesson learned" used at VCG, then it should work well in such a general setting.

Guidelines do have a much bigger role to fill and that is what the criteria attempt to describe while trying to help author write guidelines of high quality. The criteria are more adapted towards VCG but some aspects can be useful for other uses.

5.4.1 Definition compared to literature

It is clear from figure 5.9 on page 56 that the definition got a lot of inspiration from the literature which might be because many of the uses of the word in literature make sense. Many of the same uses were present in the internal documents at

VCG and a few of the uses were in the answers to the survey. The literature was vital to come up with a definition but there was a lot of work put into extracting uses and sorting out which made sense since the uses differed a lot between the different literature sources. Personnel at VCG also played a very important part in the finishing touches and there were a few meetings to make sure the definition, together with the criteria, worked for VCG.

5.5 Case study applications

This section will show the definition of a guideline and criteria being applied to some examples from the case study at VCG.

5.5.1 Analysis of specific guidelines

All of the guidelines are a work in progress and the following analysis is meant as input to improve that work by clarifying some issues and possible improvements. The requirements towards the end are in use but the use of the definition and criteria for requirements was not the intention when they were written. This leads to a very limited application but an area for future improvement.

B-shop

As short process flow as possible. This guideline is not only impossible to follow, it is also redundant since no engineer will make production lines and other parts of the process flow longer than needed. It is very hard to see how this could be possible to turn into a useful guideline. If a flow is longer than the shortest possible solution then it will be because of some other constraints but there will always be a reason.

Avoid off-line stations (example paint repairs). This guideline is missing the background and motivation which is that off-line stations add transportations which are a waste but also goes against FiFo (First in First out). It should however be explained in the guideline so it is clear why it should be considered. The motivation will also give information what will happen if this guideline is not followed, a principle is broken. When this guideline should be considered in development must also be stated.

C-shop

Receiving of external sequence flows should be positioned close to PoU (Point of Use) This guideline is also related to waste from transportation, the guideline informs the designer that incoming external flow should be received as close to where they are used as possible. In order to follow this guideline the point of use must be known which makes the prerequisite clear. How this is verified is harder to explain since “close” is vague but at an appropriately early stage in the design, when it is possible to change the layout, the check can be performed in terms of if it has been considered or not. This guideline was not part of the survey.

Components should be designed so that they can only be assembled in one way. This guideline related to product is meant to reduce the waste of time spent on finding the correct orientation of a component. It might not be very easy to follow this guideline but it is straight forward to find out if it is fulfilled or not. If many of the components cannot follow the guideline then that will be an indication of a possibly problematic situation. It is however likely that the engineers at R&D already consider this since it might be considered a fairly basic design aspect. This guideline was not part of the survey.

General guidelines (not shop specific)

Visualization of the flow is secured. This guideline is good example of a guideline which is close to impossible to follow. What is meant by visualization? What kind of visualization? It is supposed to be secured but when and how is not stated. There is also no background on why visualization is important or connections to company performance. Such information is needed in order for the guideline to be usable.

TAKT and Balance line capacity for demand (machines/shift) is evaluated. The main purpose of this guideline is a very good and important one because when you design a line there is some basic information which must be found out first. An example: the line will have demands on minimum output in number of cars per workday, the line will also have an input tact which states at what rate the cars are coming in to the line. First the line must be able to output cars at the same or a higher rate than the output demand therefore there must be enough machine capacity and workforce to achieve that. This can then be divided into the shifts to come up with staffing requirements. Depending on the input rate, there might be a higher staffing requirement if the input is close to the demanded output. These figures and basic calculations must then be performed during the design and the guideline should state this, there should also be links with more details if needed.

Every process must ensure a Safe and Healthy working environment. Starting from the first criteria of a guideline, “optional” it is hard to see that safety and health could be considered optional which is the main argument why this example should be a requirement. Regarding the content, the issue it covers is a very important one but by changing it into something like: “Make sure the process design follows the health and safety requirements according to . . . This check must be done at the . . . stage during development.” By filling in the blanks and referring to rules, requirements or standard it is possible to know the related regulations and find more information about how to do it. If the requirement states when this is supposed to be done it makes it simpler to validate all designs at an appropriate time.

Requirements from C-shop

The following sample of requirements (table 5.4 on page 63) are from the final assembly where they have collected requirements which R&D must consider and follow to make sure the product will be compatible with the final assembly. There are also considerations on wasted time so that the components are adapted to the conditions in the final assembly. The requirements below are part of a larger collection of requirements where almost all were clear requirements with clear descriptions and those are not included here.

It is not straight forward to use the definition and criteria as a framework for analyzing requirements to see if they should be turned into guidelines. This is mainly due to the intention to have the definition and criteria as a way to improve the writing of guidelines and to make their role clear among the other terms which they might be confused with. The idea for such a framework is a good one but it lies outside the scope of this master thesis. With the definition and criteria as a foundation it would be possible to develop such a framework given enough time.

The requirements from C-shop were of high quality and the examples shown are the only ones needing adjustments from a large number of requirements. This shows that the work with requirements is clearly defined at VCG and this should be the target for the guidelines.

Table 5.4: Three requirements from the Assembly (C-shop).

(a) Requirement about welding.

Restriction final assembly parts that could be welded in body shop Purpose: Minimize Tf1 time (man-hour) in final assembly. Requirement: Parts assembled on all cars that could be welded must be assembled in Body shop. The check is done virtually or physically.
The use of the word could might be interpreted as something optional. This could be changed to: "all parts which are welded must be assembled in A-shop." Or "No welding in C-shop."

(b) Requirement about contaminated parts.

No contamination on delivered parts in Final Assembly Title: MFG No contamination on delivered parts in the Final Assembly Purpose: To avoid contamination in the final assembly process. Requirement: Parts delivered shall be free from contamination (e.g., grease, oil, dirt, and glue) in the Final Assembly. If it is not possible to avoid contaminations, areas with contaminations must be marked on drawing. Verification method: Check drawing. The check shall be performed by the responsible manufacturing engineer.
Since parts are allowed to be contaminated, as long as they are marked, it cannot be a requirement. It is a guideline. Instead there should be a guideline about contamination and a requirement about marking contaminations.

(c) Requirement about glue and lubricants.

No adding of glue/lubricants on parts in the Final Assembly Title: MFG No adding of glue/lubricants on parts in the Final Assembly Purpose: To avoid glue/lubricants in the final assembly process. Requirement: Adding glue/lubricants for assembling parts is not allowed in the Final Assembly. If it is not possible to avoid glue/lubricants it must be documented on C-note, and if needed, marked areas on drawing. Verification method: Check C-note. The check shall be performed by the responsible manufacturing engineer.
It is allowed but not wanted it must then be a guideline, the C-note can still be a requirement which is connected to the guideline. The guideline should explain why it should be avoided and state possible consequences if the guideline is not followed.

5.6 Improving layout guidelines

The following guidelines about layout work are still a work in progress. By using the definition and criteria the guidelines can be improved. This section will present applications in practice and it will also show what kind of work is needed to write a good guideline. There is a fair bit of work needed but the work will improve the usefulness of the guideline and in turn the whole collection of guidelines will provide extra benefits.

Design the line/area to ensure the operator is never fixed to one station (table 5.5 on page 65). This guideline at area abstraction level wants the layout engineers to consider making sure that no operator is forced to be fixed to only one station. The operators should be able to switch the station he or she is working at as part of the regular work rotation. This puts some demands on the area layout to make sure the rotation can be performed. When drawing and planning the layout and placing stations, the walking distances between the stations and what kinds of equipment separate them must be taken into consideration.

Main aisle split all lines in the middle (table 5.6 on page 66). This guideline wants the designers tasked with layout design in the Assembly to make sure that the production lines which must be split are split in the middle of the line. Splitting might be needed to make room for people walking and other kinds of transportation. Doing so is needed to minimize transport distances and to make the new line fit in better with the existing lines.

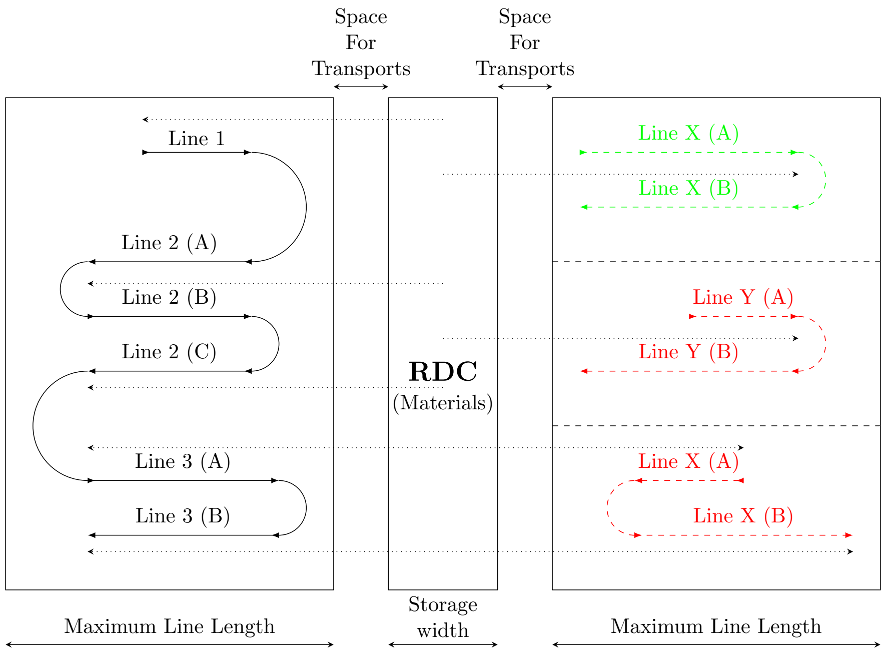


Figure 5.10: Line splitting design, green: OK suggested lines, red not OK suggested lines

Table 5.5: Guideline: ensure the operator is never fixed to one station.

(a) The original guideline.

Name: Design the line/area to ensure the operator is never fixed to one station.
Number: 117
Abstraction level: area level

(b) The parts needed to improve the guideline.

Optional: The guideline is optional to follow.
Instructional: Consider the placement of stations when designing the line and area layouts to make sure no operator is fixed to one station by analyzing the placements of the neighboring stations.
Task oriented: Measure the walking distances between each station to make sure all stations can be part of the normal work rotation. This measurement must consider that some stations and areas are off limits for walking operators. If a station must be shut down before it can be walked through, consider an alternative route.
Quantifiable: Measure the walking distance between each station (measurement in m) which are part of the same rotation.
Fact based: Every operator must be able to rotate the station to work at, this is done to introduce variation into the work. Work variation is needed to reduce the risk of injuries due to repetitive movements (ergonomics).
Referable: See "Instruction for Ergonomics work in Projects" for further information (`http://bms.volvocars.net/apps/bms/bms_vd.nsf/DocumentInfo?OpenForm&Src=viewweblink/1024160154jyt`)
Controllable: [Owner and responsible department]
Contextual: This guideline belongs in the area abstraction level, part of process guidelines.
Leveled: Is every station placed in a suitable way to facilitate normal work rotation, if not, can the layout be changed to fix this? If the layout cannot be changed to fix this there will be consequences in terms of ergonomics.
Directed to audience: This guideline is aimed to be used by area engineers.
Illustrated: see figure 5.11 on page 67.
Scenario connected: Can a walkway be added to fulfill this guideline?
Up-to-date: This guideline must be checked and updated at regular intervals when it has been approved.
Non-contradictory: This guideline is not contradictory to any other applicable guideline.
Promoting conformity: This guideline is aimed at making sure the layouts follow the standard when it comes to work rotation.

Table 5.6: Guideline: Main aisle split all lines in the middle (C-shop).

(a) The original guideline.

Name: Main aisle split all lines in the middle.
Number: 158
Abstraction level: shop level
Shop: Assembly.

(b) The parts needed to improve the guideline.

Optional: The guideline is optional to follow.
Instructional: When designing lines which are longer than the maximum distance to the RDC (Re-Distribution Center) split it in two equally sized parts. This will make the layout more visible and it will fit better with the surroundings. Following this guideline will make the solution more modular and reusable.
Task oriented: Find out the maximum length and the needed production rate. Calculate how many equally sized parts the line must be divided into to fit within the maximum allowed length.
Quantifiable: [Maximum length].
Fact based: Having equally sized line parts will make the layout more clear and shorten the driving distances for material transports.
Referable: See “vision layout presentation” (`https://sharepoint.volvocars.net/sites/leanplantdesign/Cshop/Layout%20Guidelines/vision%20layout%20presentation.pptx?Web=1`)
Controllable: [Owner and responsible department]
Contextual: This guideline belongs to a group of guidelines which describes how to make modular and standardized solutions for the Assembly.
Leveled: This guideline must be considered during layout design of the whole shop in the assembly, since there must be time available to split/change the line if needed.
Directed to audience: Everyone working with layouts for the Assembly should understand this guideline.
Illustrated: Illustrated: see figure 5.10 on page 64.
Scenario connected: Different scenarios can be made by using standardized lengths of line in combination to different production rates.
Up-to-date: Regular checks/updates must be done for this guideline.
Non-contradictory: No contradictions with other guidelines.
Promoting conformity: This guideline promotes conformity by making sure the line fit into a standard length and will therefore not interfere with the RDC (Re-Distribution Center). The lines have standardized length and this guideline is part of it. Having similar production rates are also related to this.

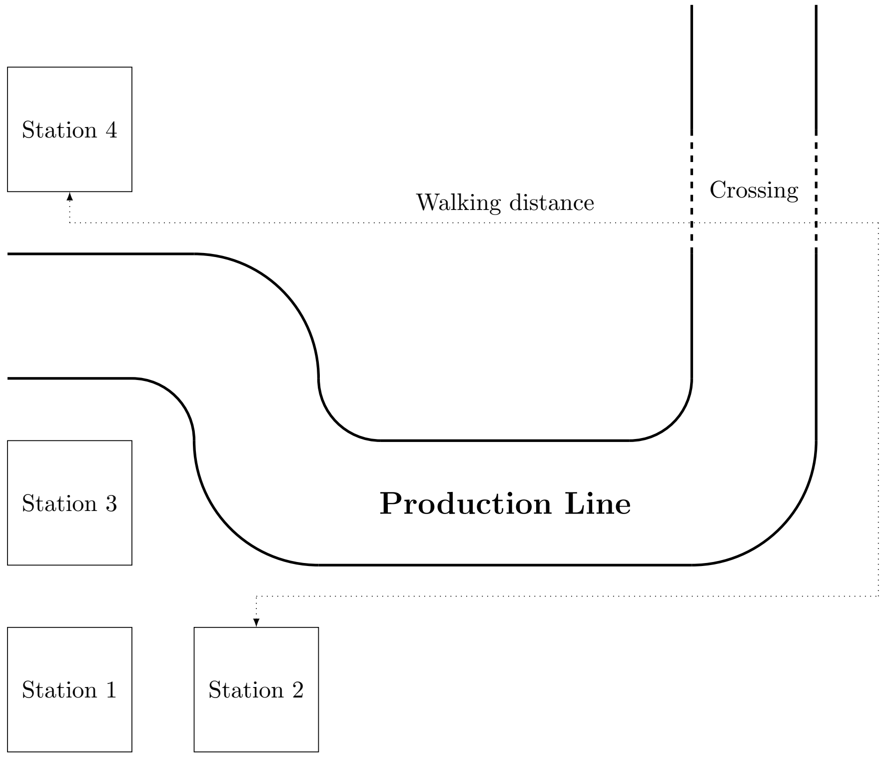


Figure 5.11: Station placement which causes long walking distances.

5.7 MEGMAS design

When designing a system one must take many aspects into consideration to have a steady ground to stand on. The users must be at the center of this process and that is why the starting point was a series of interviews about system functionality accompanied with a form of some suggested high level functions. These functions were rated by the participants and they had the opportunity to ask questions if anything was unclear, any additional input was collected as well. The functions were prioritized and then some tests were made on implementations in SharePoint to begin testing out the usability.

5.7.1 System functionalities

When starting to come up with the design of a system it is necessary to begin with the high level functionality, where the main areas are shown in table 5.7 on page 68. What should be included was based on the survey, interviews and other talks with possible future users within ME. Usability and usefulness was the main issues considered when starting the design of the MEGMAS. There were many suggestions collected from the survey (“A.1 Survey” in the Appendix) together with input from literature and more informal talks. Some additional input came from the time spent on getting to know SharePoint.

Table 5.7: Main areas of functionality considered for the MEGMAS.

Area of functionality
Information collection (high level)
Information dissemination and transfer (high level)
Information update and upgrade support (high level)
Information protocol (high level)
Information storage (high level)
Information re-usability
Amount of information
Analysis support
Content management
Wikis
Interface and layout design
Information rating
System integration
System performance

5.7.2 Rating system functionalities

First, the very long list of possible functionalities ("A.2 High level system functionalities" in the Appendix) had to be rated in terms of what could be feasible to implement during this master thesis. Functionalities shown in green were rated as absolutely possible to implement, they yellow ones could most probably not be implemented and the red ones would require much more time and resources for research to be implemented in the MEGMAS. What functionality went through to the next step of rating importance are shown in "A.3 Considered functionality" in the Appendix.

The system functionalities previously mentioned then had to be prioritized so that the most important functions received the most time and effort. There are many ways to come up with such a prioritization and using points to score importance is an easy solution. If every function is given a score from one to five, with five being most important, then the functions can be sorted according to score. One problem with this way of working is that there is a risk of very many functions receiving the highest score because everything is wanted.

Another way of working is based on the same solution but with the addition of a maximum allowed number of points to give out to the functions. If there are 30 functions with a maximum of 60 points to hand out then it is not possible to give five to all of the functions. One limitation of this is that summing up points for 30 items takes time which in practice means that computer support in the form of Excel for example is needed. This solutions also requires more time since more effort has to be given to the prioritization but if that time is available then it will also be a benefit. Such a solution will lead to more differentiation between the functions which is what is wanted.

Prioritizing of the functions based on scoring with a max score was done with the functionalities from the previous section together with Hafez Shurrab (Shurrab, 2015). The results from two people using the method showed that it worked and both had similar scoring. There were clear groups of functions with different priorities (see table A.21 on page 118).

Some of the suggested functionalities are what might be called low hanging fruit, meaning that they could be implemented easily. Many of those functions are easy to implement since that or similar functionality is available in SharePoint. Such functionalities are good to implement regardless what importance they are given, as long as they add value to the system.

5.7.3 Interviews about system functionalities

The method of having scoring with a maximum was shown to function as intended but the extra amount of time and access to computers led to using an answer sheet with no max score. With more time to perform these interviews the max score would have been used. The results from the interviews are shown in table A.23 on page 123.

One suggested way of making the community active in the MEGMAS came from literature and that solution was to use wikis (see "4.6 Information system design" in the Theory chapter). The interviews made it clear that many of the interviewees did not know what a wiki was and when Wikipedia was brought up, it was viewed as any kind of knowledge database. Having many authors to write articles with a high degree of freedom, as is the case with Wikipedia, was not known. Many of the views on wikis were negative when the concept was explained, it should be handled with meetings instead was one response. It seems like a wiki could add some value to the MEGMAS but some trial runs accompanied with information on the added value will be needed before implementation.

Another suggestion from the interviews was to have the system inform managers of knowledge areas lacking guidelines. How to make this happen without adding to much annoyance for the users is difficult and should only be considered at a later stage when most knowledge areas have enough content.

5.7.4 SharePoint

SharePoint is a software by Microsoft which is used to make interactive webpages, mainly for intranet usage. Calendars, lists, wikis and surveys are some examples of uses for SharePoint where the items can be used on their own or as part of webpages. VCG uses SharePoint for its main intranet with many pages for all departments. SharePoint provides access to many premade solutions which can be added to a web page like puzzle pieces without any need for writing code. There is built in support for version handling and access control among other things.

SharePoint was selected due to its extensive use at VCG and since it is generally more user-friendly than Excel. It also has more functionality related to version handling and data distribution. SharePoint can be used to make interactive webpages for internal use without lots of coding and other design work but if bigger changes are wanted in the functionality then additional software and coding work is needed. This thesis work only started the work in SharePoint but there is much work left since the complications surrounding guidelines demanded a lot of time and effort.

SharePoint can be integrated with the other software from the Microsoft Office suit, such as Access, InfoPath, Word, Excel, PowerPoint and Outlook. These can adapt and change content in SharePoint to customize content. More advanced changes and customizations can be made by using SharePoint Designer which gives access to more html code and other aspects of SharePoint databases. Such changes require a lot more knowledge from the designers compared to built in functionality. Automating functionality in SharePoint such as email when attention is needed in what is called workflows can, apart from very simple built in functionality, only be made with SharePoint Designer. This includes choices of where to send the email depending on the data so the appropriate person is informed.

5.7.5 Human interaction analysis of some examples of functionality

SharePoint was selected as the basis for the MEGMAS due to financial reasons and a time constraint. This does however mean that SharePoint will incur some limitations on usability, some of them are analyzed in this section. The following analysis is based on “4.7 System testing” in the Theory chapter.

Managing the abstraction levels

Under “site settings” there is an option called “Term Store Management Tool” which main purpose is to be able to use different terms in different settings or departments. This is also called information in a tree structure or taxonomies (see section “4.6.3 Content management” in the chapter Theory). This is related to adapting the sites to different users. Using the “Term Store Management Tool” is the only way that has been found to achieve a “tree”-structure in SharePoint. This is more of a “work around” than an actual solution since this is not exactly the intended use. Having

Table 5.8: PHEA of making changes to abstraction level tree.

Making changes to abstraction level tree	**Why did the mistake occur?**	**What are the consequences of the mistake?**	**Can the user identify the mistake?**	**Can the user correct the mistake, how can this be done?**
Accidentally removing term of tree structure in SharePoint	The user deleted the wrong item	Anyone editing an affected item will not be able to make changes to it until the term is restored.	Only by editing an affected guideline or while trying to add a guideline with the same abstraction level.	By adding the term and then editing all the affected guidelines.

the guidelines structured using this functionality has its limitations, mainly when it comes to usability. Making mistakes in the "Term Store Management Tool" can have big consequences for guidelines relying on it.

If the user wants to delete a term (or change it) the user must right click on the term and select delete (or double click to rename) when the terms is deleted a warning comes up, see figure 5.12 on page 72. The warning message is not very clear in terms of describing the consequences of the action the user is about take. What the message is describing is that any item dependent on the term which is about to be deleted, including sub terms, will be placed in a group of "orphans" (they belong nowhere). But it is not easy to understand the consequences this will have for lists (like the list of guidelines) where the items will be there but they will be locked for modifications before a valid term has been selected. Any change to the affected guideline cannot be saved before the problem with the term is fixed, see figure 5.13 on page 72. It might be good that SharePoint tries to make sure every guideline has a valid abstraction level (term) but if the abstraction levels are managed by someone else than the one wanting to make a change, then it will take some time to resolve the problem.

This way of relying on terms for the structure of guidelines is not very robust since the removal of a term can have big consequences and there is no logging of changes to the terms. The only way to fix the affected items in to add the term again but all the affected guidelines must then be edited to use the new item. This must be done even if the term is added with exactly the same name since every new term has its own unique ID which SharePoint relies on. If a term with many associated guidelines is deleted there will be a lot of work needed to restore it. This

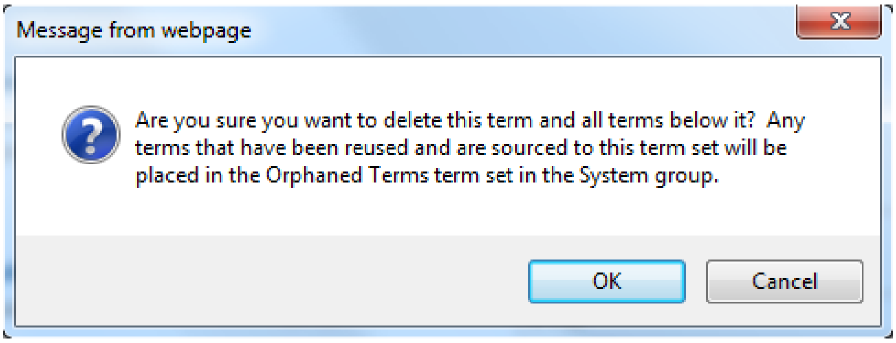


Figure 5.12: Warning when deleting a term in SharePoint.

problem is of high priority to be solved since it has a big impact and it will be very hard for most users to understand what is wrong.

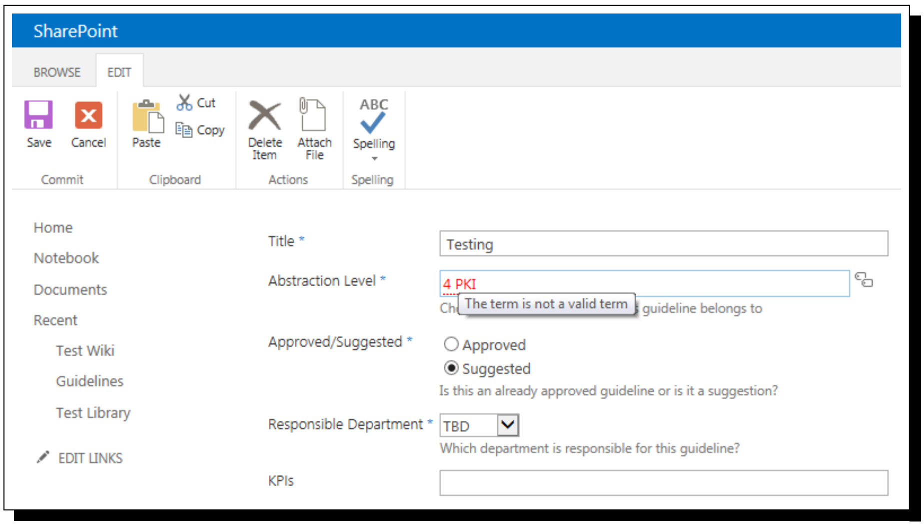


Figure 5.13: Missing term (abstraction level) in SharePoint for a guideline.

Selecting the abstraction level of a guideline

When clicking on a symbol of label to select the term (abstraction level) the user must expand the tree view to find the appropriate level and then the user must double click on the term to select it. The user can also click on select to make sure the correct abstraction level is assigned to the guideline, see figure 5.14 on page 75. If the user only clicks once on the abstraction level and then OK the previous or standard abstraction level will be applied to the guideline. The user must notice this mistake while in a view in which the guideline shows up. This means that in views with filters that were intended for the guideline will not work with the incorrect abstraction level and the guideline will therefore not be shown.

Table 5.9: PHEA of selecting the abstraction level of a guideline.

Selection the abstraction level	**Why did the mistake occur?**	**What are the consequences of the mistake?**	**Can the user identify the mistake?**	**Can the user correct the mistake, how can this be done?**
Only clicked once on a term and then OK	The user must double click or click once and then click on "Select" before clicking OK	The guideline will have the previous or standard abstraction level	Yes, by looking at the abstraction level of the guideline, if it is not noticed then the guideline will not show up when it should	Yes, by editing the guideline, selecting correct abstraction level and double clicking on it and then on OK.

Changing a filtered view

If a user want to change the view of the guidelines to suit the current task the user can base the setting on a previous view rather than having to start from the beginning. If there is a view with a parent item somewhere far down in the tree and the user is interested in a child item then it is quicker to start with that view and change the filter to a child item. The problem with this is that the current filter is only shown when the tree is expanded enough to show the abstraction level on which the filter is applied, figure 5.15 shows the expanded tree with a check mark next to the current filter on page 76. This task is analyzed in table 5.10 on page 74.

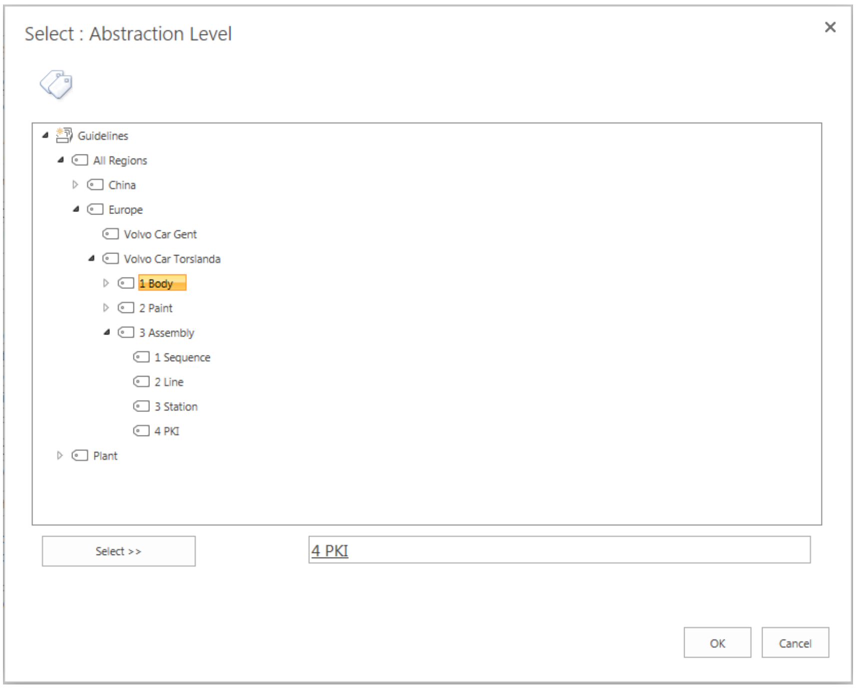
The tree view does add extra difficulties in terms of usability, mainly due to constraints in SharePoint. A possibility to sort the guidelines in a tree structure is also needed since its extensive use in BoP and other hierarchical structures. Filter can also be made using the settings in SharePoint where all users who can view the list can make personalized views only available for them (or shared with others) but that option is more complicated and the example shown here is the easiest way to do it. It probably is not easy enough though which is problematic since the MEGMAS should be used by as many as possible and the only way to get acceptance is that the system adds enough value compared to the work needed to operate it.

These examples intended to show that there is a lot of functionality built into SharePoint which can be used for the MEGMAS but that there are problems of

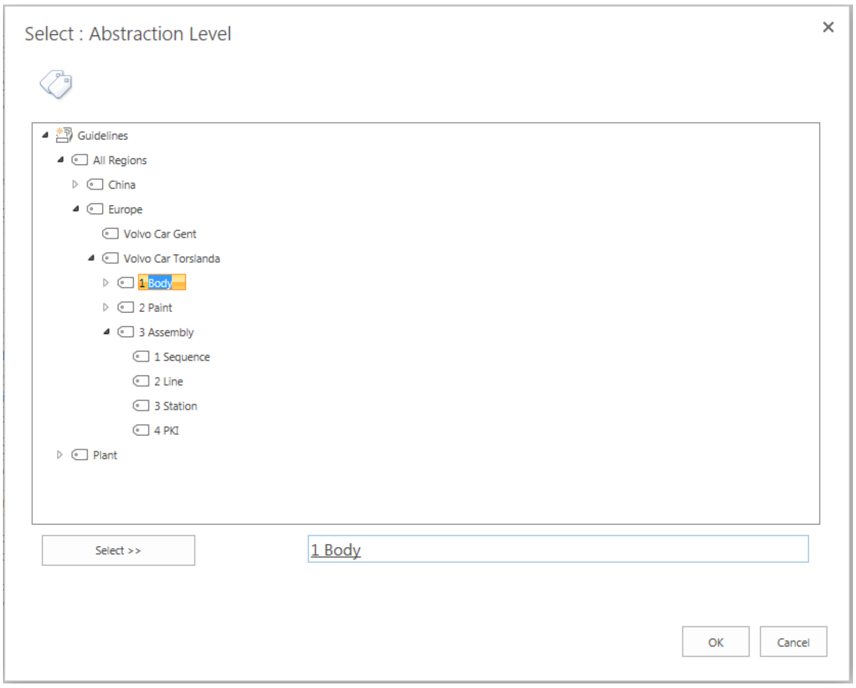
Table 5.10: CW of changing the filtered view in SharePoint.

1 Changing the filtered view	**Response**	**Problem**
Does the user attempt to make the right choice?	NO, the user cannot see what filter is applied and tries to click clear filters.	When opening the column settings the checkmark for the filter is not shown.
Is the right choice clear enough to be discovered by the user when it is accessible?	YES, if the tree in the column settings is expanded enough.	
Is the right choice connected with the wanted operation by the user?	NO, the user does not expand the tree since it is not evident what filter is applied.	The checkmark indicating the current filter can only be seen when the tree is expanded enough.
Can the user notice the progression if the right choice is made?	YES, the new view with the new filter is displayed.	

usability for many of them. The built in functions can greatly reduce the time needed to make the MEGMAS but this time saved comes at a price, reduced usability. If the functions are to be rebuilt from scratch or if big changes are to be made to improve usability then there is a need for a lot of time and it also requires access to more advanced tools such as SharePoint Designer. Such changes could not be fit into this master thesis with the available time but it serves an indication on where to continue after the thesis work.

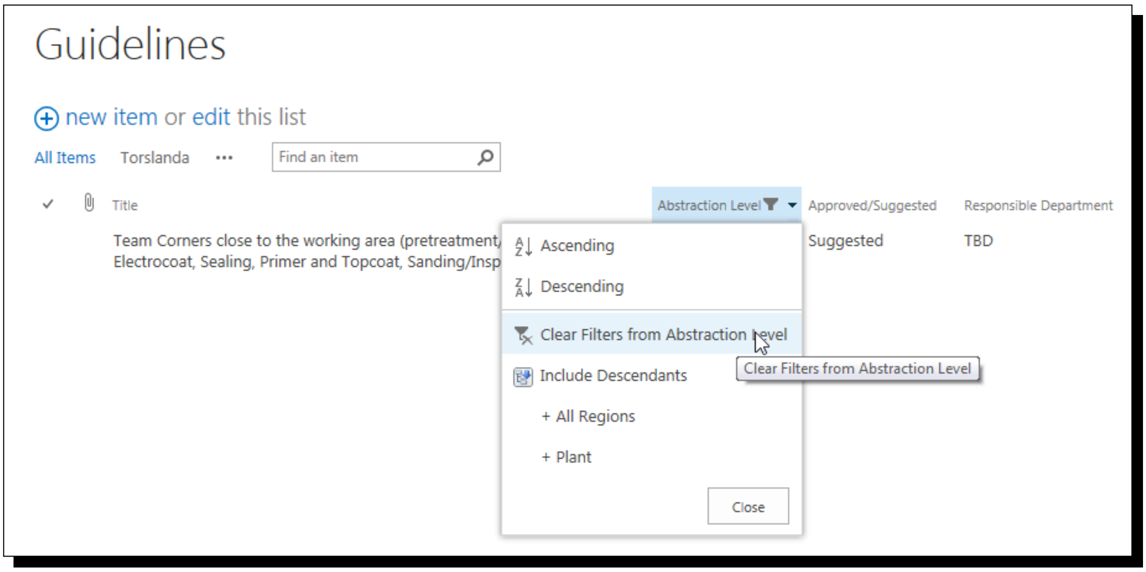


(a) The user has clicked on "1 Body" but the selection has not changed.

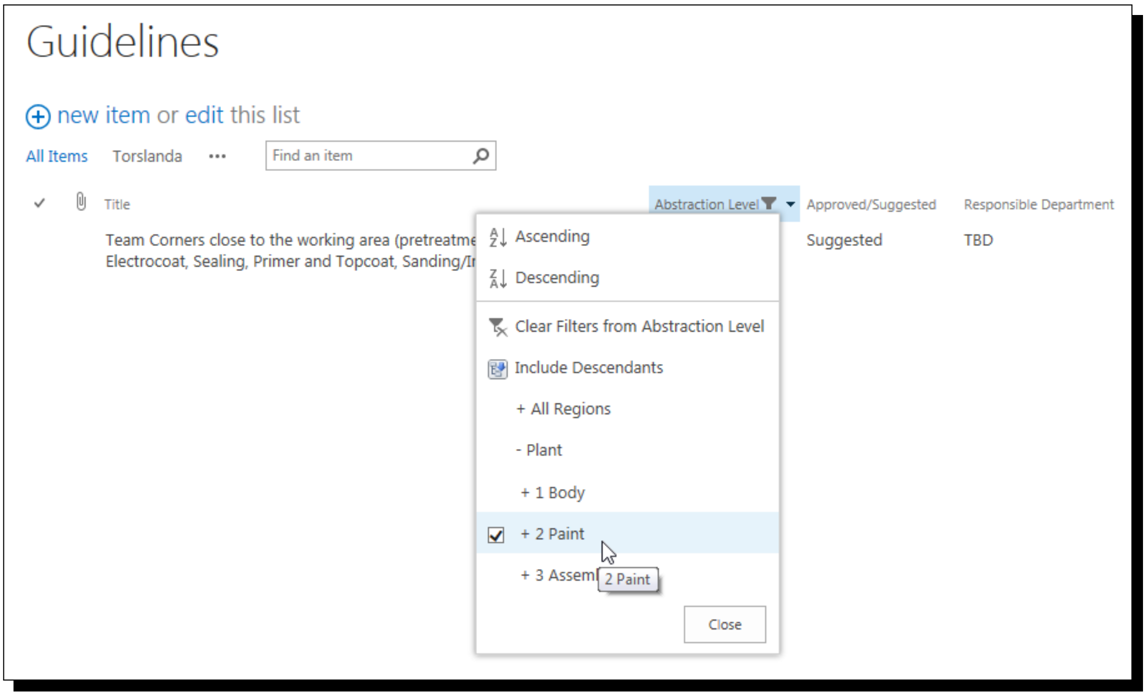


(b) If the user double clicks on "1 Body" or clicks once on it and then on "Select" at the bottom, then "1 Body" is selected as intended.

Figure 5.14: Selecting abstraction level in SharePoint.



(a) A filter is being applied in SharePoint but what filter is not shown.



(b) When the tree in SharePoint is expanded it is clear that the view is filtered on “2 Paint”.

Figure 5.15: Changing the filter settings in SharePoint.

6

Discussion

DISCUSSION will discuss some of the main results of this master thesis by highlighting the authors views on this master thesis as a whole. There will also be some discussion about the lack of results in some areas and other comments about how this master thesis turned out.

6.1 Expert author

The topic of expert authors is a very interesting one in terms of the quality of written guidelines. When writing guidelines it is important to make sure all of the audience understands the guideline and when you are an expert mainly working with other experts it might become a challenge. The survey showed vast experience of the participants from ME and is probably one reason why the scoring of most of the guidelines were so uneven. When you are an expert you tend to think that many aspects which could be part of a guideline are so self-explanatory that you choose to disregard them. The criteria for a good guideline can hopefully help this issue by stating what content is needed in a guideline no matter the skill level of the author. This master thesis can hopefully help even more with writing good guidelines and the two examples of improved guidelines shows what kind of work is needed to achieve this.

6.2 Sustainable Development

The environmental implications of this master thesis are most likely nonexistent since the social and economic impacts are the main ones. If the development of cars can become more efficient there could be some positive environmental effects in the long term. With guidelines related to environmental considerations the MEGMAS can of course provide benefits but the system on its own may probably not.

Social benefits are more likely to come out of a better way to manage guidelines and giving support on how to write them. By giving engineers extra support with good examples, rules of thumb and what they should consider when designing production environments there will be a way to find out what to do and to keep the knowledge up to date. This can also provide extra support for new and inexperienced personnel so they can find what they are looking for without the need to frequently ask colleagues.

If the MEGMAS can assist in making sure information is kept and that previous decisions are not forgotten then the time spent on development can be reduced. The development itself costs a lot of money but it has another potentially big consequence in terms of losing ground to competitors with a delayed product launch. Another economic benefit is that the MEGMAS can assist in getting consultants up to speed on what is happening and what is yet to be done. If consultants and other personnel are about to leave then the MEGMAS can be a place to store information related to the continued developments.

Sustainable development is an important topic to consider during development and since many costs are related to product design incurred during development such considerations must be done. All projects cannot satisfy or impact all of the three areas of sustainable development but one should try to impact as many in a positive way as possible. This master thesis can still provide benefits to sustainable development and since the social and economic areas are very important it is still a good result. How big of an impact is hard to know since the development work is complicated and takes a lot of time before the results show. Another reason is that much of the development process is very important to a car manufacturer and it is therefore surrounded by secrecy, included the time used to develop a car.

6.3 Time to market

Time to market is the complete time needed to develop a new car, the development which include personnel from ME is a substantial part of the total development time. During this time it is made sure that the car can be produced in the factories according to specifications, there is also a lot of work spent to make sure the connections between the factories and shops work as they should. This work can be more efficient by making sure the development is done right and that no decisions are lost.

If an engineer can design a production environment without the need to first arrange meetings with other departments with assistance from the MEGMAS then the work can be done quicker. How quickly is clearly dependent of the quality of the guidelines in the MEGMAS and that is why there has been so much effort put into making sure the guidelines are clearly defined. The associated criteria can then give authors and mangers of guideline support to keep the quality of the guidelines at a high level. Usability is very important for the MEGMAS but it is equally important that the guidelines are of use to the engineers and other users.

6.4 Limitations of the research

There were some limitations on how much content could be included in the report and how many topics could be analyzed. The main deficiency in the actual results compared to the wanted results is that the building of the MEGMAS was not done far enough to begin user tests. Many reasons can be attributed to this, some of which were out of mine and my colleague Hafez's (Shurrab, 2015) control. One of those reasons is even though we were two people gathering the results, we had to write two separate reports. This of course meant that there was a lot more time spent on writing reports than what was planned in the beginning. The role of guidelines was another topic which demanded more time than was planned for initially. Guidelines are so fundamental for the MEGMAS and there was a real need to thoroughly describe the guidelines to know what kind of information to keep in the MEGMAS. A clear description of guidelines was also needed to help the authors of them by making it clear how to write good and useful guidelines.

The question of time to market, as mentioned earlier, is another clear limitation in terms of the results and this is another question where the complexity of it was underestimated in the beginning of this master thesis. How to get new car models to market is of course a very important question but answering it is very difficult. Another aspect which makes the topic of time to market difficult is that any concrete numbers of the time used for the steps in the development of new car models are company secrets of VCG and therefore cannot be mentioned in this master thesis. It then becomes more difficult to estimate any time saved with a new system but it would still be far from straight forward to do such estimations even if the times used would be allowed in the content.

6.5 Research at VCG

It cannot be overstated that it was an absolute joy to perform this master thesis at VCG, thanks to all the involvement and support from the people at ME. Both me and Hafez Shurrab received phenomenal support from all the staff we came in contact with and they all seemed eager to make sure the work would be as good as possible. There was a lot of work to get to know VCG for the scope of the thesis and one would have a hard time to get to know the whole of VCG due to its size and complexity. Hopefully this master thesis can contribute to the development of VCG and also help other students working with VCG.

7

Conclusion

CONCLUSION will go through the main conclusions. The main results are first stated and after that the research questions with brief answers to them. Lastly, the proposed further research which could benefit from having this master thesis report as a starting point.

7.1 Main results

7.1.1 Theoretical results

The main theoretical result from this master thesis is a definition of a guideline which compared to many of the current definitions provides a more clear role and use for guidelines.

7.1.2 Practical results

- How guidelines are used at VCG.
- The borders between guidelines, requirements, KPIs and standards.
- Definition of a guideline, suitable for use at VCG.
- Criteria to assist writing good guidelines.
- How to write good guidelines with examples.
- High level functionality for a system which is suitable for managing guidelines.
- Some examples of how to analyze usability.
- Highlighting some issue with usability in SharePoint.

7.1.3 Answers to the research questions

"How can time to market for car development projects be shortened by removing uncertainties for engineers on where and how to find specific requirements/guidelines affecting their work by using a MEGMAS?" With input from for example Lessons Learned turned into guidelines stored in the MEGMAS there will be more support to achieve "right from me" and "first time through" which will shorten the development time. The requirements are handled in a very structured way and the systems are well known throughout VCG. This is not the case for manufacturing guidelines and it is evident that MEGMAS could be of real use for VCG, at least for the ME department.

"What are the differences between academic definitions of requirements/guidelines and the definitions used at VCG?" One main conclusion is that there are so many definitions which in the end means that there is no real agreement, not in academia and not at VCG. This will hopefully change soon since this master thesis has come up with a definition and criteria which are usable at VCG.

"Is it possible to find definitions of requirements and guidelines based in academia that still satisfy the needs of VCG and if so, how should they be defined?" The definition presented in this master thesis which was developed in collaboration with Hafez Shurrab (Shurrab, 2015) satisfies every party involved within ME at VCG and that definition was largely based in academia. What the other departments think about the definition is a bigger task than fits in this master thesis but the research of company documents could not find any definition in any of the material.

"What are the important aspects of the MEGMAS which will be used to manage manufacturing design and development guidelines, how does that translate into specific functions?" The central aspect is usability as previous examples have shown that no matter the quality of the system: it is the users who make the system successful. How to make the users happy and make a system that provides the users with what they want and need is the main issue. What the users at VCG want has been presented in terms of high level functionality and examples of tests which can assess usability have been presented.

7.2 Further research

- The main point which really could benefit from more research is the implementation of the MEGMAS and to make it as integrated as possible to be of use for as many people at ME as possible.
- Trying to implement all or most of the suggested system functionalities suggested for the MEGMAS in the Appendix would improve the usability aspects even more and also the likelihood of success in terms of usage at ME.
- There have been some opinions and wishes for a system or framework which can be used to analyze requirements to make sure they fulfill the properties

of a requirement and if not how should the information be classified instead, as guideline for example. The results from this master thesis could form the basis for development of such a framework.

- It would be very useful to come with abstraction levels for product and process aspects for production development. If there is a possibility for these abstraction levels to be the same for all shops and there is a way to come to an agreement between all the shops and all the departments of ME it would be even more useful.

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A

Appendix

A.1 Survey

Table A.1: Participants of the survey.

	# asked	# answered
A-shop	3	1
B-shop	3	0
C-shop	4	0
Not tied to a shop	9	7
Total:	19	8

Table A.2: Work experience from the survey.

# of years at VCG	# answers
3	2
15	1
16	1
17	1
18	1
19	2
20	2
25	1
28	1
30	3

How long (in years) have you been working at Volvo Car Group? (optional)

B-Shop
C-Shop

Table A.3: Years at current position from the survey.

# of years at VCG	# answers
0	2
1	1
2	5
3	2
5	1
7	1
8	1
9	1
14	1
15	1

How long (in years) have you been working at your current job (position)? (optional)

Table A.4: Purposes of guidelines according to the survey.

Purpose	# of answers
Support following the best practice of an action.	13
Support decision making concerning issues you have previous knowledge about.	12
Support decision making concerning scenarios and implications development.	8
Support knowledge related to requirement, KPI or standard contexts.	7
Get notification or warning for potential deviations.	5
Support to get focus on right manufacturing aspects of a new part/system.	1

For which of the following purposes would you mainly use DGM (multiple choices are allowed)?

Table A.5: Possible sources of DGM according to the survey.

Source	**# of answers**
Lessons Learned after a project is handed over.	17
Previous studies	12
Customers	8
Requirements	8
Suppliers	4
Consulting firms	3
KPIs	3
Standards	3
Lessons Learned (issues) during a project.	1
Deviations in plant	1
Engineerings meeting	1
Previous studies	1

What are the common sources of DGM? (i.e. from where does a guideline usually originate from?) (multiple choices are allowed)

Table A.6: Possible abstraction levels for product, from the survey.

Abstraction level	# of answers
Main product level	12
Embedded system level	12
Subsystem level	12
Component level	11
Business strategy	7
PSS level	2
Work approach	1
Process station	1
Functions	1
I do not know	1

How many abstraction levels should guidelines support for products? (use your own terms in the free-text box)

Table A.7: Possible abstraction levels for process, from the survey.

Abstraction level	# of answers
Shop level	13
Area level	13
Plant level	12
Line level	12
Station level	12
PSS level	1
Work approach	1

How many abstraction levels should guidelines support for processes? (use your own terms in the free-text box)

Table A.8: Rating of guidelines for the A-shop from the survey.

Guideline					
Very early on we should have a strategy for the Maximum production volumes output and "end state scenario" for the plant. This is to avoid bad locations of the flows and to make an efficient Body shop long term.					
Rating					
Fits more other terms than a guidelines (e.g. requirement)	**1, Major changes required**	**2**	**3, Minor changes required**	**4**	**5, Good to use**
1		1			4

Guideline					
People flow: should be considered as well. Lower need if high grade of Automation.					
Rating					
Fits more other terms than a guidelines (e.g. requirement)	**1, Major changes required**	**2**	**3, Minor changes required**	**4**	**5, Good to use**
		1		2	3

How do you rate the following sample of guidelines related to A-Shop according to your own opinion about how a guideline should be (Rating is for how well the guidelines are formulated and supportive)

Table A.9: Rating of guidelines for the A-shop from the survey (continued).

Guideline					
Instability in the planning cascades costs down into the organisation and wastes time in getting to our targets (however there will always be need for change and we need to try and absorb this with minimal disruption).					
Rating					
Fits more other terms than a guidelines (e.g. requirement)	**1, Major changes required**	**2**	**3, Minor changes required**	**4**	**5, Good to use**
1		1	1	2	1

Guideline					
From this base data we should create blocks for each process island defining output and push for the process islands.					
Rating					
Fits more other terms than a guidelines (e.g. requirement)	**1, Major changes required**	**2**	**3, Minor changes required**	**4**	**5, Good to use**
			1	1	4

Guideline					
It is often MP&L and our process areas that suffer due to too small building.					
Rating					
Fits more other terms than a guidelines (e.g. requirement)	**1, Major changes required**	**2**	**3, Minor changes required**	**4**	**5, Good to use**
2	1		1	1	1

How do you rate the following sample of guidelines related to A-Shop according to your own opinion about how a guideline should be (Rating is for how well the guidelines are formulated and supportive)

Table A.10: Rating of guidelines for the B-shop from the survey.

Guideline					
Short process flow as possible.					
Rating					
Fits more other terms than a guidelines (e.g. requirement)	**1, Major changes required**	**2**	**3, Minor changes required**	**4**	**5, Good to use**
2	1	3	1		1

Guideline					
Working heights to be defined in function of the operations to perform on the station.					
Rating					
Fits more other terms than a guidelines (e.g. requirement)	**1, Major changes required**	**2**	**3, Minor changes required**	**4**	**5, Good to use**
3		2	1	1	1

Guideline					
Avoid off-line stations (example paint repairs)..					
Rating					
Fits more other terms than a guidelines (e.g. requirement)	**1, Major changes required**	**2**	**3, Minor changes required**	**4**	**5, Good to use**
1		2	2	2	1

How do you rate the following sample of guidelines related to B-Shop according to your own opinion about how a guideline should be (Rating is for how well the guidelines are formulated and supportive)

Table A.11: Rating of guidelines for the the B-shop from the survey (continued).

Guideline					
Close distances between manual working areas/stations.					
Rating					
Fits more other terms than a guidelines (e.g. requirement)	**1, Major changes required**	**2**	**3, Minor changes required**	**4**	**5, Good to use**
2		2	2	2	

Guideline					
Empty container return flow (fork lift traffic etc.).					
Rating					
Fits more other terms than a guidelines (e.g. requirement)	**1, Major changes required**	**2**	**3, Minor changes required**	**4**	**5, Good to use**
2		2	2	1	1

How do you rate the following sample of guidelines related to B-Shop according to your own opinion about how a guideline should be (Rating is for how well the guidelines are formulated and supportive)

Table A.12: Rating of guidelines for the C-shop from the survey.

Guideline					
Aim for same complexity per platform on main line, move complexity to subassembly lines. Variant creation outside mainline.					
Rating					
Fits more other terms than a guidelines (e.g. requirement)	**1, Major changes required**	**2**	**3, Minor changes required**	**4**	**5, Good to use**
1	1	1		1	

Guideline					
Modular areas: Even amount to have short return loop: Pretrim: 30JPH 2 lines - 60JPH 4 lines, Decking: 30JPH 2small lines - 60JPH 2long lines.					
Rating					
Fits more other terms than a guidelines (e.g. requirement)	**1, Major changes required**	**2**	**3, Minor changes required**	**4**	**5, Good to use**
		2		1	1

How do you rate the following sample of guidelines related to C-Shop according to your own opinion about how a guideline should be (Rating is for how well the guidelines are formulated and supportive)

Table A.13: Rating of guidelines for the C-shop from the survey (continued).

Guideline					
Receiving of external sequence flows should be positioned close to PoU.					
Rating					
Fits more other terms than a guidelines (e.g. requirement)	**1, Major changes required**	**2**	**3, Minor changes required**	**4**	**5, Good to use**
2			2		

Guideline					
End flow: no crossing of finished cars, test track and material flow.					
Rating					
Fits more other terms than a guidelines (e.g. requirement)	**1, Major changes required**	**2**	**3, Minor changes required**	**4**	**5, Good to use**
1			3		

How do you rate the following sample of guidelines related to C-Shop according to your own opinion about how a guideline should be (Rating is for how well the guidelines are formulated and supportive)

Table A.14: Rating of general guidelines (apply to all shops) from the survey.

Guideline					
Visualization of the flow is secured.					
Rating					
Fits more other terms than a guidelines (e.g. requirement)	**1, Major changes required**	**2**	**3, Minor changes required**	**4**	**5, Good to use**
3		4	6	1	4

Guideline					
TAKT and Balance line capacity for demand (machines/shifts) is evaluated.					
Rating					
Fits more other terms than a guidelines (e.g. requirement)	**1, Major changes required**	**2**	**3, Minor changes required**	**4**	**5, Good to use**
5		3	3	4	3

Guideline					
Every process must ensure a Safe and Healthy working environment.					
Rating					
Fits more other terms than a guidelines (e.g. requirement)	**1, Major changes required**	**2**	**3, Minor changes required**	**4**	**5, Good to use**
6	2	3	1	3	3

How do you rate the following high-level guidelines (Rating is for how well the guidelines are formulated and supportive).

Table A.15: Issues with the guidelines in the survey (comments).

What are the main issues you found in the previous sample of guidelines? (examples: too simple, not specific, should be grouped/ordered chronologically, need knowledge and example support (e.g. pictures), do not support decision making etc.)
I have not read them.
They must be more specific.
Not specific.
Health & safety should be a standard to follow.
Not so much, the thing is to write in a simple way so the message is clear and simple.
The spread of useful info and not so useful info is a bit big.
Some need to be expanded for clarity. Some are more demands than guidelines.
Not specific enough to provide guiding. Too general.
Too simple, more of a wish list or a checklist. It should be connected to some kind of a best practice and better defined.
Too generic and the reason behind is not defined/documented. Need to support the user more!
Need knowledge and example support (e.g. pictures).
I don't understand the question.
Not general enough and bad picture quality.
It's for me a "demand" and criteria to go on to the next step; Takt & Balance: Cruisal to have that parameter as a prerequisites Safety & Healthy: Also to secure that attributes are ensured. For me this is more indicators (KPI in "ME language") that should be followed during the project
Some of the examples have a stronger relationship to the processes describing the way of working than guidelines. For example, "TAKT and Balance line capacity for demand is evaluated" should be secured through operational development. 2. Some of the examples can be categorized as requirements/standards.
Should be quantified.

Table A.16: Solutions for the guidelines in the survey (comments).

From your experience, what kind of solutions should be considered in DGM in order to be useful for manufacturing engineers (e.g. synchronized with project milestones, integrated into SharePoint as a list etc.)?
Don't know.
Be very specific, use pictures!
Easy access Updated frequently - wiki page Based on plant structure.
DGM need to be stored and presented in a system that all engineers can reach and understand, most likely a DGM per shop, good info that engineers needs to consider during the engineering phases for product (Not requirements).
Easy to filter, to make this tool complete for an A shop it will be massive by the time you are finished and to avoid putting people off using it it should be well structured and easy to filter.
Possible to select area and function annual vs industrialization phase could be interesting.
See above.
Easy to find and clearly written.
Easy to find what you need.
Knowledge of robustness for different type systems on a specific part/function.
DGM are established to document the experience and knowledge and to provide a base for design work. DG is not a technically binding document, but shall be used internally Volvo Car Corporation as a guide to best practice. Experience from Lessons Learned, quality issues, etc. are examples of things that can be documented in the DGM.
There must be at PSF gate, an acceptance agreement sign off, of the DGM from all project parts being affected of the guidelines. E.g. Design Engineers.
I think that in a perfect cycle the team evaluate continuously the Lessons Learn / Knowledge / Demands and sort them in resp. category with some overall principles. I think that working with visualization like pictures ”not like this” vs. ”make it like this” could be one way to increase the level to follow and read the guidelines. Also split in ME Generic and Area Specific.
The DGMs must be easy to work with (e.g., logically structured and accessible for all MEs) and changes shall be traceable. The guidelines must be a part of program-work using , for example, checklists at each milestone. However, how this is implemented efficiently is not trivial.

Table A.17: DGM storage according to the survey (comments).

Where are most of the DGM related to your area stored?
Not applicable.
No were today regarding product DG, for Process in Lean Plant Design SharePoint.
Specifications for the simulation models, files on disk.
Scattered.
BMS and lessons learnt (lotus).
R&D / TCE.
TCe.
FMEA, PII, PVS, DMAIC, (VQDC, Lessons learned).
In shared disk.
BMS (mine are more about describing a way of working, like instructions ...).
Currently, we do not have DGMs as requirements are used for all Mfg demands on the product.
TeamCenter.

Table A.18: Retrieval of DGM according to the survey (comments).

How do you retrieve the DGM related to your area?
As LL from factories.
Not applicable. We are not working towards DGM only requirement -TCr.
Disk.
Had to collect them together myself.
Lotus Notes databases, W. disk and own disk.
Talking to R&D.
TCe.
FMEA, PII, PVS, DMAIC, (VQDC, Lessons learned).
Not at all.
From the shared disk.
Requirements in TeamCenter.
TeamCenter.

A.2 High level system functionalities

Table A.19: All possible functionality for the MEGMAS

Functionality
Information Collection (High Level)
Guidelines are gathered (from design and knowledge engineers) and approved by all sponsors on a regular basis.
The procedures to propose a guideline are clearly described.
Supporting information required to work with the guidelines are provided and updated on a regular basis (e.g. manuals and tutorials).
Information from users (i.e. complaints and ideas) are gathered on a regular basis.
Information about new technologies and functionalities to be integrated are provided on a regular basis.
Comments and reflections on particular guidelines are enabled - Function.
Calls for cross-functional team meetings to discuss particular guidelines and therefore initiate a related workflow is possible through the system.
Managers and sponsors are enabled to have a discussion (forum) about the implications of the changes on the actual work and the firm in general - Function.
Surveys for measuring the common understanding of design and knowledge engineers are facilitated - function.
External knowledge is channeled into the guidelines pool and referenced once observed. This means that proposing a guideline could include a reference to check how much external information is explicated and internalized - Function.
The lessons learned process is connected to the guideline system automatically through synchronizing proposal requests with the project milestones at which lessons learned are usually extracted - Function.
The benchmarking process is connected to the guideline system automatically through synchronizing proposal requests with the benchmarking events - Function.
Guideline proposals enable scenario development - Function.
Guideline proposals enable quantifications and related links to calculations/calculators that estimate recommended figures to be considered - Function.

The system must provide support for authors of guidelines to improve their quality. This also needs good and bad examples. Definition and criteria will help as well - Property/Function.

State what supporting documents are needed and why - Function.

Information dissemination and transfer (High Level)

Guidelines are accessible by everyone in the organization - Function.

The procedures to propose a guideline are clearly shared with all potential contributors.

Simple single and multiple guidelines sharing is enabled for all viewers - Function.

Changes in a guideline category or management system (or cluster) are shared with corresponding stakeholders on a regular basis - Function.

Experts (know-how knowledge) in the topic of a particular guideline (considering the degree of expertise) are visible - Function.

Inquiries related to a particular guideline topic are enabled - Function.

Guidelines with the highest rate of use and actual support frequency are formally shared to their customers on a regular basis (weekly digest) as proactive support - Function.

The organization's databases and documents related to guidelines can be accessed through computer networks - Function.

Guidelines databases are referred to with direct hyper-link in as many information systems as possible within the organization - Function.

Information manipulation: selected guidelines are possible to be exported as lists or lists with related wikis or any possible form of information that could be useful and handy from user perspective (e.g. checklists with specially named and formatted column headers) - Function.

A group of guidelines should have a specific community - Function.

Information update and upgrade support (High Level)

The minimum effort to easily discard obsolete guidelines (or parts of them) and search for new alternatives (e.g. new parts of guidelines, new complete guidelines, new clusters of guidelines etc.) is enabled - Function.

Changing the structure of guidelines categories is flexible.

Changes in individual system aspects and routines are independent as much as possible.

Information protocol (High Level)

There is some industrial order or protocol for the performance of guidelines management.

Stakeholders are assigned including sponsors, users, managers, collaborators, experts etc. and designated for the corresponding guidelines, and their role description and accountability are clearly stated - Function.

KPIs are defined for the different guidelines management roles (especially for experts and sponsors) - Function.

The procedures for the different forms of automatic and manual data collection concerning guidelines inquiries and validation are clearly defined and systematically described.

Information storage (High Level)

Users are able to attach different sorts of multimedia to a particular guideline - Function.

The databases are large enough to support fast processing performance considering the expected growth of knowledge to be continually gathered from experts and other types of users - Function.

Information Re-usability

Information gathered from contributors should enable usable guidelines, meaning that the information feeders should be designed so that contributors clearly understand what to be provided and which level of details is satisfactorily required. This functionality could be based on the suggested criteria of supportive guidelines - Function.

Amount of Information

Different modes/settings of description detail level are enabled, starting from a simple list with a few columns to lengthy paragraphs with plenty columns - Function.

The switch between settings are simple and quick - Function.

Analysis Support

The system enables analytical operations to be applied by users through picking up and screening particular data upon request. (Example: generating potential risks or causes of problems is possible by selecting a group of guidelines and drawing scenarios whereby the fulfillment of the selected guidelines are experimented) - Function.

The system enables analytics for user behavior while using the system - Function.

The system enable installing extras and add-ons that support qualitative and quantitative analysis of guidelines - Function.

Content management

The abstraction level of a guideline should be aligned with the corresponding aspect category - Function.

Guidelines should be smartly filtered in with the least number of steps possible - Function.

Guidelines should be properly tagged with related keywords that have different validity and weights in order to enable productive guidelines search and filtration - Function.

Design guidelines should particularly tagged as to be primarily related to a method, a process, or a product - Function.

The logical structure of guidelines (adapted taxonomies) network/tree follows standards - Function.

Each particular piece of information related to a guideline is possible to be found easily and quickly through metadata including notes, authors, keywords, dates etc. - Function.

Guidelines have unique ID/Codes - Function.

Wikis

Knowledge in documents related to the terminology and concepts included in a guidelines should be extracted in wikis that enable immediate and direct knowledge acquisition when needed - Function.

Wikis allow multimedia support - Function.

Wikis have a community of experts who approve information, and a community of system supporters who sort out information according to the protocol and standard structure and format - Function.

Interface & Layout Design for Humans

The technical detail of the control panel user-interface corresponds the level of system expertise of actual users. Technical features could be hidden in the beginning and exposed as the actual active time spent on the system goes by. Once an aspect is uncovered, users are informed about for what purpose and how it is used using integrated help (overlay tutorials) - Function.

The system design patterns are aligned with organizational standards and commonality (Skeuomorphism) - Function.

Minimalism is considered (glossy icons are replaced by simpler one-color versions or text-based buttons, rich gradients with simple solid color combinations) - Function.

Laser focus is considered (to puts visual focus on a single, obvious task to do once a user opens the web application, instead of providing several equally important options) - Function.

Context sensitive navigation is considered to enable hiding unnecessary details in dynamic user interfaces.

Collapsed content is considered (hiding non-essential options and widgets under one link which will expand and collapse on a user's request) - Function.

Content chunking is considered (presenting a large amount of content in smaller visual chunks, so it's easier for people to read and mentally digest) - Function.

Long pages with scrolling are enabled instead of several pages - Function.

Avoid relying on short term memory unless absolutely needed, consider the risks with this. Example: One could report a certain guideline by have the possibility to see the information without the need to remember what it includes, Function.

The system can adapt to the knowledge level of the user.

The system can highlight important details for expert users since, experts have a tendency to miss details by seeing the whole picture.

Frequent reminders are used to make sure things are kept in the user's memory - Function.

The system will make sure the user has enough time and it does not present too much information, this is done to avoid the user taking shortcuts and acting biased - Function.

The system provides extra support for complex tasks, Function.

Trends or checklists are used when the user is dealing with large amounts of information - Function.

Data is presented in a way which requires as little analysis as possible (is the data needed for a decision presented in the best way) - Function.

It must be easy for the users to find out the functionality of the system and what it can help with - Function.

Information Rating

Guidelines should be able to be rated and reported by users to assess their usability and level of quality and validity - Function.

Direct users should be asked to periodically rate the guidelines they are assigned to in order to ensure their validity (and as part of continuous improvement).

Experts (from certain degree of expertise and upward) should be able to assess risk rate and describe potential implications if a guideline/group of guidelines is/are not considered properly - Function.

Guidelines are rateable in terms of potential contradiction/consistency as opposed to all guidelines. Contradicted guidelines are possible to be visibly specified for a guideline - Function.

Integration with other systems

The actions related to guidelines could be processed in other systems (such as design artifacts), and thus establishing links leading directly to the closest points of use is a credit for the system - Function.

Guidelines are possible to be exported into compatible file types commonly used in design and development functions - Function.

System performance

The processing of action operations is naturally instantaneous.

The system is capable to maintain its desired deliverability in light of the available users to be supported.

No errors appear for enabled operations such as filtrations and searches.

The system is able to inform users when it is misused about how it should be properly used and the possible reasons of misuse.

A.3 Considered functionality

Table A.20: Functionality considered for the MEGMAS.

Area	**Functionality**
Information collection	Comments and reflections on particular guidelines are enabled
	Managers and sponsors are enabled to have a discussion (forum) about the implications of the changes on the actual work and the firm in general.
	Guideline proposals enable scenario development.
	The system must provide support for authors of guidelines to improve their quality. This also needs good and bad examples. Definition and criteria will help as well.
	State what supporting documents are needed and why.
Information cascading and transfer	Guidelines are accessible by everyone in the organization.
	The procedures to propose a guideline are clearly shared with all potential contributors.
	Simple single and multiple guidelines sharing is enabled for all viewers.
	Changes in a guideline category or management system (or cluster) are shared with corresponding stakeholders on a regular basis.
	The organization's databases and documents related to guidelines can be accessed through computer networks.
	Guidelines are possible to be exported into compatible file types commonly used in design and development functions.
Information Governance	Stakeholders are assigned (including sponsors, users, managers, collaborators, experts etc.) and designated for the corresponding guidelines, and their role description and accountability are clearly stated.
Information storage	Users are able to attach different sorts of multimedia to a particular guideline.

	The databases are large enough to support fast processing performance considering the expected growth of knowledge to be continually gathered from experts and other types of users.
Information quality assurance	Information gathered from contributors should enable usable guidelines, meaning that the information feeders should be designed so that contributors clearly understand what to be provided and which level of details is satisfactorily required. This functionality could be based on the suggested criteria of supportive guidelines.
Content Management	The abstraction level of a guideline should be aligned with the corresponding aspect category. Guidelines should be smartly filtered in with the least number of steps possible. Design guidelines should particularly tagged as to be primarily related to a method, a process, or a product. Guidelines have unique IDs/Codes. Knowledge in documents related to the terminology and concepts included in a guidelines should be extracted in wikis that enable immediate and direct knowledge acquisition when needed.
User-interface and Layout Design	Long pages are enabled instead of several pages, to avoid having to click next many times. Frequent reminders and supportive text are used to make sure things are kept in the user's memory. The system will make sure the user has enough time and it does not present too much information, this is done to avoid the user taking shortcuts and acting biased. It must be easy for the users to find out the functionality of the system and what it can help with.

A.4 Rating of system functionalities

Table A.21: Scoring of functionality for the MEGMAS by the two students.

Functionality	**Score**
Comments and reflections on particular guidelines are enabled	3
Managers and sponsors are enabled to have a discussion (forum) about the implications of the changes on the actual work and the firm in general.	2.5
Guideline proposals enable scenario development.	1.5
The system must provide support for authors of guidelines to improve their quality. This also needs good and bad examples. Definition and criteria will help as well.	4.5
State what supporting documents are needed and why.	3.5
Guidelines are accessible by everyone in the organization.	1.5
The procedures to propose a guideline are clearly shared with all potential contributors.	1
Simple single and multiple guidelines sharing is enabled for all viewers.	2.5
Changes in a guideline category or management system (or cluster) are shared with corresponding stakeholders on a regular basis.	2.5
Guidelines are possible to export into compatible file types commonly used in design and development functions.	2
Stakeholders are assigned (including sponsors, users, managers, collaborators, experts etc.) and designated for the corresponding guidelines, and their role description and accountability are clearly stated.	4
Users are able to attach different sorts of multimedia to a particular guideline.	2
The databases are large enough to support fast processing performance considering the expected growth of knowledge to be continually gathered from experts and other types of users.	1
Information gathered from contributors should enable usable guidelines, meaning that the information feeders should be designed so that contributors clearly understand what to be provided and which level of detail is required. This functionality could be based on the suggested criteria of supportive guidelines.	3

The abstraction level of a guideline should be aligned with the corresponding aspect category.	3.5
Guidelines should be smartly filtered in with the least number of steps possible.	2.5
Design guidelines should tagged as to be primarily related to a method, a process, or a product.	3
Guidelines have unique IDs/Codes.	2
Knowledge in documents related to the terminology and concepts included in a guidelines should be extracted in wikis that enable immediate and direct knowledge acquisition when needed.	2
Long pages are enabled instead of several pages, to avoid having to click next many times.	1.5
Frequent reminders and supportive text are used to make sure things are kept in the user's memory.	2
The system will make sure the user has enough time and it does not present too much information, this is done to avoid the user taking shortcuts and acting biased.	2
It must be easy for the users to find out the functionality of the system and what it can help with.	3.5

A.5 Interview about functionalities

Table A.22: Interview form about functionalities for the MEGMAS

Please read through all aspects before scoring them.	Name:
System aspect	**Importance (between 1 and 5, max: 5)**
1. Information Collection	
1.1. Comments and reflections on particular guidelines are enabled.	
1.2. Managers and sponsors are enabled to have a discussion (forum) about the implications of the changes on the actual work and the firm in general.	
1.3. Guideline proposals enable scenario development.	
1.4. The system must provide support for authors of guidelines to improve their quality. This also needs good and bad examples. Definition and criteria will help as well.	
1.5. State what supporting documents are needed and why.	
2. Information cascading and transfer	
2.1. Guidelines are accessible by everyone in the organization.	
2.2. The procedures to propose a guideline are clearly shared with all potential contributors.	
2.3. Simple single and multiple guidelines sharing is enabled for all viewers.	
2.4. Changes in a guideline category or management system (or cluster) are shared with corresponding stakeholders on a regular basis.	
2.5. Guidelines are possible to be exported into compatible file types commonly used in design and development functions.	
3. Information Governance	

3.1. Stakeholders are assigned (including sponsors, users, managers, collaborators, experts etc.) and designated for the corresponding guidelines and their role description and accountability are clearly stated.	
4. Information Storage	
4.1. Users are able to attach different sorts of multimedia to a particular guideline.	
4.2. The databases are large enough to support fast processing performance considering the expected growth of knowledge to be continually gathered from experts and other types of users.	
5. Information quality assurance	
5.1. Information gathered from contributors should enable usable guidelines, meaning that the information feeders should be designed so that contributors clearly understand what to be provided and which level of details is satisfactorily required. This functionality could be based on the suggested criteria of supportive guidelines.	
6. Content Management and information transformation	
6.1. The abstraction level of a guideline should be aligned with the corresponding aspect category.	
6.2. Guidelines should be smartly filtered in with the least number of steps possible.	
6.3. Design guidelines should particularly tagged as to be primarily related to a method, a process, or a product.	
6.4. Guidelines have unique ID/Codes.	
6.5. Knowledge in documents related to the terminology and concepts included in a guidelines should be extracted in wikis that enable immediate and direct knowledge acquisition when needed.	
7. User-interface and Layout Design	
7.1. Long pages are enabled instead of several pages, to avoid having to click next many times.	

7.2. Frequent reminders and supportive text are used to make sure things are kept in the user's memory.	
7.3. The system will make sure the user has enough time and it does not present too much information, this is done to avoid the user taking shortcuts and acting biased.	
7.4. It must be easy for the users to find out the functionality of the system and what it can help with.	

A.6 Average rating of functionalities

Table A.23: Average scoring of functionality for the MEGMAS during interviews

Functionality	Score
Comments and reflections on particular guidelines are enabled	2.43
Managers and sponsors are enabled to have a discussion (forum) about the implications of the changes on the actual work and the firm in general.	1.86
Guideline proposals enable scenario development.	3.43
The system must provide support for authors of guidelines to improve their quality. This also needs good and bad examples. Definition and criteria will help as well.	4.43
State what supporting documents are needed and why.	3.58
Guidelines are accessible by everyone in the organization.	5
The procedures to propose a guideline are clearly shared with all potential contributors.	4
Simple single and multiple guidelines sharing is enabled for all viewers.	3.57
Changes in a guideline category or management system (or cluster) are shared with corresponding stakeholders on a regular basis.	3.57
Guidelines are possible to export into compatible file types commonly used in design and development functions.	4
Stakeholders are assigned (including sponsors, users, managers, collaborators, experts etc.) and designated for the corresponding guidelines, and their role description and accountability are clearly stated.	3.86
Users are able to attach different sorts of multimedia to a particular guideline.	4.71
The databases are large enough to support fast processing performance considering the expected growth of knowledge to be continually gathered from experts and other types of users.	4.43
Information gathered from contributors should enable usable guidelines, meaning that the information feeders should be designed so that contributors clearly understand what to be provided and which level of detail is required. This functionality could be based on the suggested criteria of supportive guidelines.	3.43

The abstraction level of a guideline should be aligned with the corresponding aspect category.	3.57
Guidelines should be smartly filtered in with the least number of steps possible.	4.57
Design guidelines should tagged as to be primarily related to a method, a process, or a product.	4.14
Guidelines have unique IDs/Codes.	4.43
Knowledge in documents related to the terminology and concepts included in a guidelines should be extracted in wikis that enable immediate and direct knowledge acquisition when needed.	2.57
Long pages are enabled instead of several pages, to avoid having to click next many times.	3.57
Frequent reminders and supportive text are used to make sure things are kept in the user's memory.	3.71
The system will make sure the user has enough time and it does not present too much information, this is done to avoid the user taking shortcuts and acting biased.	3.71
It must be easy for the users to find out the functionality of the system and what it can help with.	4.71