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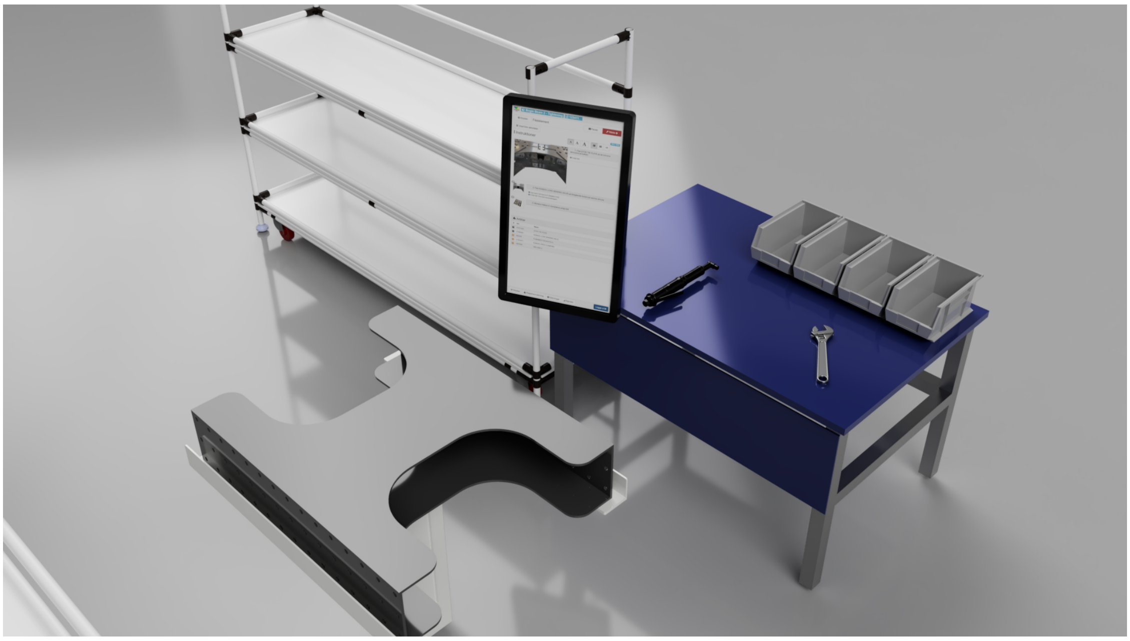

Digital Dynamic Work Instructions in a Variant Driven Industry

An Investigation on the Effects of Dynamic Instructions on Operator User Satisfaction

Master's thesis in Production Engineering

EMIL ASKLUND

RICKARD ERIKSSON

Department of Industrial and Materials Science
CHALMERS UNIVERSITY OF TECHNOLOGY
Gothenburg, Sweden 2018

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Supervisor: Dan Li, Production Systems
Industrial Supervisor: Pierre Johansson, Volvo GTO
Examiner: Åsa Fast-Berglund, Production Systems

Master's Thesis 2018
Department of Industrial and Material Science
Division of Production Systems
Chalmers University of Technology
SE-412 96 Gothenburg
Telephone +46 31 772 1000

Cover: Digital representation of demonstrator used during the project.

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Abstract

Assembly operators of today need more support than ever from their assembly instructions due to the increase of variants. One way to support them and increase their user satisfaction is to use digital dynamic instructions. Digital dynamic instructions refers to up-to-date instructions that are varied between operator depending on their needs and skill levels. Only necessary information should be presented. It also aims to support the operator with integrated built-in quality control. The tests in this thesis show that operators take well on the use of digital platforms and they appreciate increased support in the form of images, descriptive text and quality control. The user satisfaction is positively affected by having better instructions. It is also acknowledged that having too much support and task confirmation can be hindering for an experienced operator.

Keywords: Information, Quality, Instructions, Production, Motivation, Dynamic, Digital, Individual, Cognitive, Ergonomics.

Acknowledgements

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Emil Asklund and Rickard Eriksson, Gothenburg June 2018

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1
Introduction

This chapter presents a background and purpose of the project, it includes research questions that will be answered throughout the report.

1.1 Background

In an industry where variants are a key aspect of the production, it is important that the operators that are assembling the products are supported by their work instructions. As the number of product variants increases, it's not unusual that products can be assembled in more than one way, operators, therefore need a reliable, easy-to-use supportive system to maintain an efficient, high-quality production system.
Depending on the content, individual operators may have a different perception of their work instructions. An experienced operator may need less information than a novice and this is something that motivates research within the area. It can be assumed that having too little or too much information available will have consequences on an operators user satisfaction and performance.

Many operators memorize variants instead of following the instruction material, Johansson et al[1]. According to Johansson et al[2], there is also a lack of standardization when creating the instructions within global production networks. Even more problematic is that there can be local differences between production units in the same factory.

This thesis project is a part of GAIS - Global Assembly Instruction Strategy, a project carried out by Chalmers University of Technology and Volvo together with other industrial partners, which previously has argued that large multinational companies usually want to centralize corporate functions to reduce costs, this creates the problem of big companies being slow to make company-wide changes for new entities[1][3].

1.2 Aim

This project aims to investigate the potential of dynamic digital instructions as a future platform for providing user-customized assembly instructions and the effects this will have on the operators. The dynamic instructions may also lead to better cognitive ergonomics for the operators and in extension, better quality on the product.

The demonstrator will be used as a platform for designing and testing dynamic digital work instructions. These work instructions will then be tested with real operators with different skill sets and characteristics. Analysis and evaluations of the test results will be the framework for future development and assessment of digital work instructions within Volvo Group. The area of interest is the operators experience with the new instructions in comparison with the current. Based on the research aim, two different research questions were formulated;

- Are there any identifiable trends concerning dynamic work instructions and operator satisfaction?
  - Dynamic work instructions refers to the possibility to adapt and customize the amount of information, support and confirmations the operator receives and gives the system. Operator satisfaction refers to the cognitive support and ease of use the operators receive from using a dynamic system in comparison to a static, non-dynamic instruction set.
- What are the major intrinsic and extrinsic factors affecting the operators perception of dynamic work instructions?
  - Intrinsic factors refer to the measurable informational content of the instructions, including obvious errors such as unneeded and incorrect information. Extrinsic factors are linked to the operators' perception of instructions and include how the information is presented etc.

1.3 Delimitations

The demonstrator that previously has been constructed does not contain all specifications, abilities, and properties of the real production system. Even though not all features are similar between real world and demonstrator, the major properties that are of interest to be analyzed are simulated. The demonstrator and the tests performed in this project represents and are limited to manual assembly.

Casat, the software used for the design digital work instruction in this project does not allow for some of the customizations that were suggested in the initial planning report by Volvo. This is due to it being in between two version releases. Casat will therefore not completely represent the the initial software requirements stated in the GAIS project. The general requirements of the GAIS project can be seen in Appendix A.1

The number of tests may be limited by the number of operators available in different experience categories since all operators that will participate in the tests are all working in different areas of the production at the Volvo plant in Tuve, Gothenburg.

2

Theoretical Framework

This chapter presents the basic theoretical theories and foundations that are used to shape the methodology of the project. Several frameworks by previous authors will be described and their findings will be used to discuss the results of this thesis.

2.1 Informational quality problems

Previous research has shown that there are problems with informational quality in work instructions. A framework of work instructions created by Haug[4] includes 15 different dimensions that affect work instruction quality. The framework includes five different intrinsic dimensions, defined as:

- *Deficient* information
- *Ambiguous* information
- *Unneeded* information
- *Incorrect* information
- Too *repetitive* information

The first type, *deficient* information, refers to missing information. The term *deficient* is used instead of incomplete to specifically refer to missing information.

Ambiguous information refers to information that may be interpreted in more than one way, which may be a type of incomplete information.

Unneeded information refers to information that is not needed or supportive for an operator or individual to complete a given task.

Incorrect information is when the given information is false, an example of this might be when the information says "push the red button" to perform the desired function, but in fact, the button to perform this function is blue.

The last problem, too *repetitive* information, is a type of unneeded information, but specifically refers to when the information sender gives the same information too many times.

The five different informational problems stated above are visualized in figure 2.1, in this figure, the link between given instructions and needed instructions are shown, and how these links are affected by different, intrinsic informational problems.

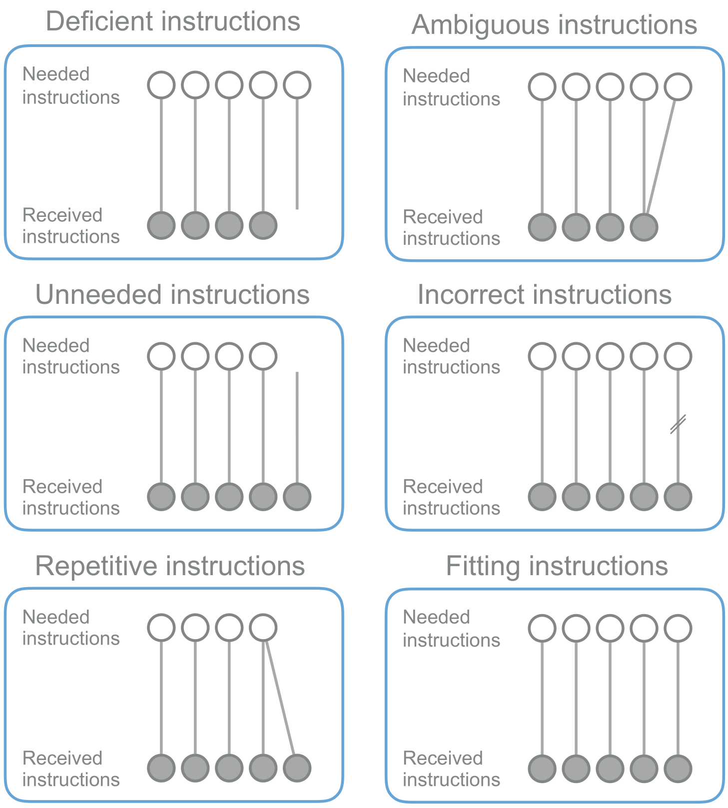


Figure 2.1: Intrinsic information quality, relation between needed information and received information. Original by Haug[4].

The intrinsic dimensions of work instruction quality are measurable as it is possible to find a relationship between 'needed instructions' and 'received instructions.'

Extrinsic information quality dimensions are more dependent on the context and can, therefore, be harder to evaluate. The different dimensions of extrinsic problems are often linked to the individual's perception of information, for example, what is 'too much' information for one individual may be 'just right' for another.

Different extrinsic informational dimensions are derived in the framework as:

- *Representational* problems - Problems related to how the information is presented.
- *Unmatched* information - Problems related to the informational content.
- *Questionable* information - Problems related to the operators trust towards the information.
- *Inaccessible* information - Problems related to barriers that prevents operators from getting information.

Within these four different dimensions, there are several different problems stated in the framework that are considered relevant[4]. These can by seen in figure 2.2.

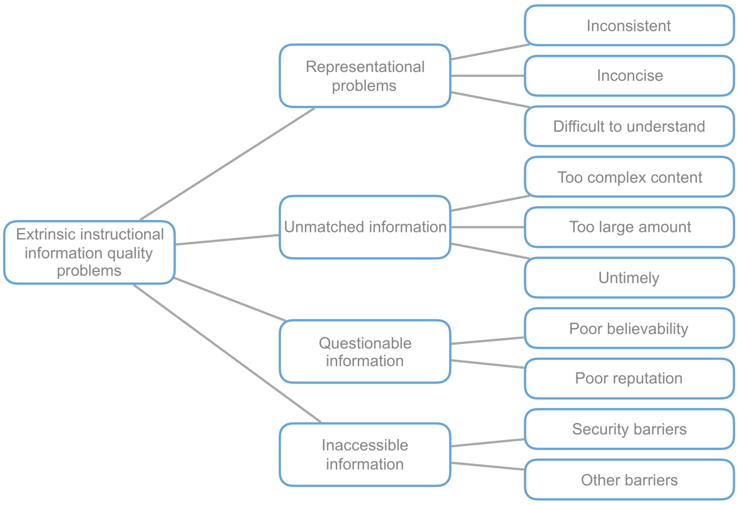


Figure 2.2: A framework of extrinsic problems in instruction information quality. Original by Haug[4].

2.2 Information success

DeLone and Mclean[5][6][7] have for almost three decades researched and refined what the variables behind successful implementation of Information Systems (IS) are and how they are connected. Figure 2.3 displays the connections, and its components are described in the following paragraphs.

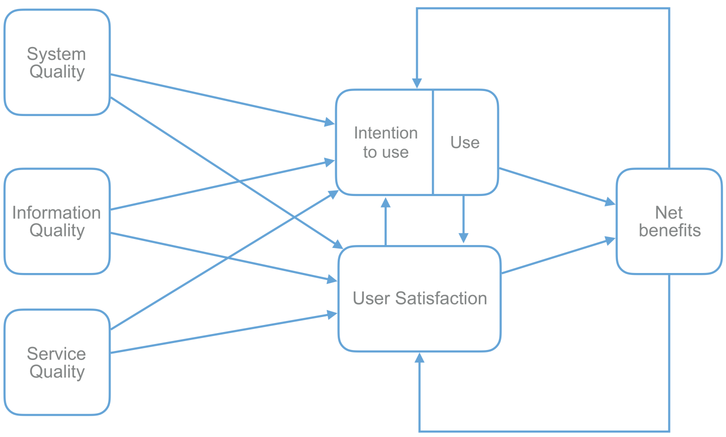


Figure 2.3: Information success framework, original by DeLone and Mclean[7].

System quality refers to the ease of use, functionality and flexibility of the system. The user of the system is a critical component identified predicting the success of the information system. In this case, the attitude towards technology, technology experience and self-efficacy are the most affecting aspects of an operator. They conclude that the technological self-confidence is a factor behind information system success. However, it can be overcome with training to help the user feel more comfortable in the system[5]. One thing to keep in mind is that quality of the system has not yet been connected to the involvement of the users (As in, they help create the system). User involvement, on the other hand, has been connected to the satisfaction of the user.

Information quality as Petter, DeLone and Mclean[5] refer to is very much connected to the framework by Haug[4] it includes for example sufficiency, understandability and conciseness.

Service quality refers to the responsiveness and support users receive in regards to the information system, in this project that would be the support the engineers and management provide the user when changes and fixes are needed in the information system.

Intention to use is in regards to if the system is used as intended, which is measured from the users' belief that they will use the system. The primary factor identified here is the attitude towards technology and confidence in using technology. However, the authors point out that task compatibility (i.e., how much the systems supports the task) may be a critical component, yet to few studies has been made to make a connection.

The *Use* category has however received clear connections to task compatibility, extrinsic motivation, management support and self-efficacy among others. The overall indication is that the real usage of a system is dependent on that it supports the task, the user is confident in its usage and that there are support, motivation and communication from management and organization. The area of user involvement need further studies to verify, however when users are more involved in the implementation and design they are more likely to use the system.

User satisfaction is the key to understanding the success of the system. The most influencing factors to the user satisfaction are task compatibility, attitude towards technology and user involvement. It also shows the importance of the communication and support between users and management to ensure that they are satisfied with the system, and therefore use it.

The *Net Benefits* as described by Petter, DeLone and Mclean[5] are the actual end effects that are received by the information system. Net Benefits means that the operator and organization have positive results from it, for example, cost reductions, higher productivity and improved decision making.

The model also describes the determinants of an information system success. The determinants are the factors that are more or less the prerequisites for success. They affect the end result, i.e. the information system success, directly. These factors decide the end effect. The factors are listed in the following list which is a selection of the complete list[5]. The main five characteristics are the domain which the related variables are sorted under;

- Task, determinants related to the work activities
  - Task difficulty
  - Task variability
- User, determinants related to the individuals characteristics and knowledge
  - Attitude towards technology
  - Attitude towards change
  - Trust

    - User expectations
    - Self-efficacy
    - Technological experience
    - Age
    - Gender
    - Education
- Social, determinants related social influence in a group (peer pressure)
    - Image
    - Visibility
    - Peer support
- Project, determinants related to the processes to develop and implement an information system
    - User involvement
    - Relationship with developers
    - Developer skill
    - Developer approach
    - Project management skills
    - Time since IS implementation
    - Voluntariness
- Organizational, determinants related to the organizational structure and support the information system receives.
    - Management support
    - Extrinsic motivation
    - Management processes
    - Organizational competence
    - IT infrastructure

2.3 Cognitive support

In an environment where customer customization demand is continuously increasing, so is the amount of variants an assembly operator needs to learn. It is therefore vital to increase the support for the operators and to ensure that they are cognitively supported by their work instructions to minimize the cognitive load[8]. Insufficient work instructions that rely on worker expertise and experience are today commonplace [9]. A drive to make the information more easily acquired[10] as well as making it more adaptable depending on the operators skill level is needed to increase the well being and performance of the operators[9].

2.3.1 Learning, Operational and Disruptive model

Mattsson presents in her PhD thesis, Towards increasing operator well being and performance in complex assembly[11] the Learning, Operational and Disruptive model which describes the 3 steps of cognitive processes an operator has to go through in their work. The phases by Mattsson are described with input on how the assembly material should support these phases in the experiment part of this thesis.

Learning Phase: The operator is actively learning something new, they need to be aware and reasoning which is a necessary phase for every operator to go through. This phase should be well supported by the assembly material.

Operative Phase: The operator is working based on experience and previous knowledge. This is the ideal phase to some degree, the operator can work without minimal support. Support, mainly for quality, should be provided by the assembly material.

Disruptive Phase: The operator has to stop and figure out a solution. They need to use their knowledge, intuition and reasoning. This phase is time-consuming and may not yield good results if the operator makes the wrong decision. With proper support, the disruptive stage should be avoided.

In the paper by Fast-Berglund and Blom[12], it is stated that pictures and movies can be used to support a cognitive task which should help reduce the cognitive overload an operator might experience when they receive to much text-based information[13].

2.3.2 Design principles For Information Presentation

Mattsson[11] also presents "Design principles For Information Presentation" (DFIP) version two, which is a design guide that supports the design of cognitive work instructions. The design is divided in to the six following steps:

1. Choose a work task in the workplace where the presentation of information needs improvement
2. Identify and support active cognitive processes in each sub-task
3. Analyse tasks based on how the operator perceives their work environment
4. Analyse tasks which depend on cognitive limitations
5. Analyse tasks which depend on individual differences and needs
6. Analyse tasks which depend on the placement of information content and carrier

2.4 Qualification of people in Industry 4.0

Industry 4.0 was introduced in 2011 as the next industrial revolution. The advantage of Industry 4.0 is to increase the adaptability and decision making of organizations by having a constant flow of real-time data. The source of the real-time data is the improved digital communication and connectivity between systems, products and people[14].

Industry 4.0 contains a digitalisation, a drive for less analog information and more real time, constantly updated information. This means that there is no place for physical paper instructions in a 4.0 industry. Papers cannot be changed after they are printed and are a unnecessary waste of resources.
It is the first two stages in the model towards Industry 4.0 that are part of the digitalisation. Stage 1, Computerisation, is when digital information systems are used independently of others. The digital information systems are needed in all machines before stage 2 can be implemented. Stage 2, Connectivity is when the machines and MES communicate with each other and therefore allowing for real-time data and better traceability of for example quality issues[14]. There are 4 more

stages in this model, but the Stage 1 and 2 are the subjects that will be touched upon in this thesis.

New implementation of technology towards Industry 4.0 will require new skills within the workforce in companies. Former, historical, major changes in the industrial world have changed the labor market and the educational system, and it is expected to see such a change again as Industry 4.0 becomes more established. It is also anticipated that some job positions disappear, and new ones to be created[15], however, this is disputed by other sources. Existing people in a current workforce are retained because of their knowledge about the manufacturing process, and as the process is changing the workforce also need to change and adapt.

Former research shows a clear dependency between an individuals age and their perceived importance of digital communication services, especially at lower ages. Communication services in the study are categorized in social media, SMS, instant messaging, phone calls, email and regular mail, and there's a dependency in importance and user intensity between social media and all other digital communication services (except phone calls and physical letters) [16].

2.5 Design for assembly

To assure an easy assembly of products, a process called DFA (Design for assembly) should be applied to the product development phase. The DFA process is closely linked to the DFM (Design for manufacturing) process which focuses on the manufacturing of one individual component, while DFA focuses on the assembly of more than one product. Up to 70% of a product's manufacturing costs are determined already at the design stage, and therefore a supportive method is needed to make an efficient design and manufacturing process [17]. In the manual assembly process, there are two separate main areas, handling, and fastening [18]. There are many advantages to use a method for DFA, in surveys, it is seen that three of the main advantages of DFA are:

- Improved quality and reliability.
- Reduction in assembly time.
- Time-to-market improvement.

The material handling process in a manual assembly system refers to the acquiring, movement and orientation of the material. There are several ways that the handling of a product can be made easier through improved design, some of them are[18]:

- Maximum symmetry.
- Obvious asymmetry where symmetry cannot be achieved.
- Features that will prevent jamming or tangling.
- Avoid parts that are very small, sharp, heavy or dangerous to handle for the operators.

For the fastening activities, there are many different ways of which a design can be improved to support the operator. Some features that will affect fastening of parts are:

- Standardization of common parts used in different assemblies.

- Provide guiding chamfers between parts.
- Provide good clearances between parts.

3 Methodology

This chapter presents the methodology and methods used in the project. It includes the research approach, methods for data collection, and information about the test subject used to gather data.

3.1 Research approach

The approach for the project was a mixed method research design. More specifically the convergent parallel design as described by Creswell and Plano Clark[19]. Since the quantitative data collected during the project was lacking due to small sample size, the qualitative data was used to support, interpret, and strengthen the quantitative data. They complement each other and allows for a deeper understanding than a single type of data would allow. The convergent parallel design is a method where the collection of both types of data is done simultaneously but independently and then, in a later stage are merged and creates a concluding result. The main advantages that are very fitting for this project are that the method is very time efficient, both data collections can be conducted at the same time. Connections between the data can then be analyzed at a later point when time is not the major limitation.

For the quantitative data, that meant fixing errors and entering them into a computer program for statistics[19]. In this case, JMP was used to conduct full factorial design of experiments which requires a minimum of 12 tests, due to three skill levels and four informational levels. The aspects that were analyzed in JMP are time and quality in reference to the level of skill and the instruction type.

For the qualitative data, the primary task was to organize, code and interpret the data. This included transcribing interviews, putting observations into text and to categorize answers from different operators in a comprehensible way[19].

Grounded theory was also used during the thesis. It allows for the development of theory outside of established frameworks. The theory is built on the analysis of collected data and not beforehand [20]. After the analysis connections were drawn to existing literature and similarities and differences will be discussed in later chapters.

The thesis roughly followed the order listed in figure 3.1. Some stages were not be completed before the next one began, this is because many of the processes are iterative and had to be revisited to ensure that the answers yielded at the end of the project were in line with the research questions. The convergent parallel design (mixed method) will be part of the end of the flowchart, specifically the analysis of interviews, observations och measurements to create a perspicuous view of the situation.

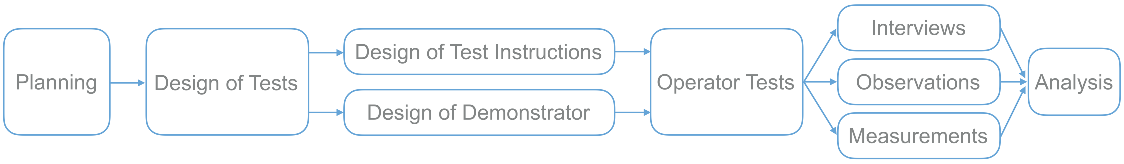


Figure 3.1: Work flow

3.2 Test parameters

During the planning phase a discussion with the supervisors of the project and leaders of the GAIS project was held regarding which aspects are suitable to investigate. It was decided that the operators would be categorized in three levels. The instruction in four different informational levels, and the product would have two variants. The plan was to test all skill levels against all the instructional levels to get reliable data and to observe what each operator needs and prefer to support their work.

The three experience levels are listed below;

- Novice
- Intermediate
- Expert

Operators placed in the category 'Novice' have never worked on or built the sub-assembly (bogie) that is used in this report. These operators usually work in other departments of the manufacturing at the Volvo Tuve plant. The 'Intermediate' category refers to operators that have been working on or built the sub-assembly one or a few times, typical operators in the intermediate category have been part of a temporary workforce. Operators in the 'Expert' category regularly works at the sub-assembly.

The Instructional information level is divided into four different instructions;

- As is
- Basic
- Dynamic Novice
- Dynamic experienced

'As is' refers to the current work instruction used in the actual production known as Sprint. The three other categories are different instructional information levels created in Casat, each containing more assembly support than the other. The purpose of these different variants is to gauge how much assistance and operator need and prefer depending on their experience level.

3.3 Current product and production

The product studied in this project was the bogie beam, also known as cross member, shown in figure 3.2. The bogie connects the two parallel chassis beams of the truck as can be seen in 3.3. It also has the role of carrying a lot of electronics such as ABS, EBS and RCIOM control units. It also carries mechanical components such as air tanks and fastening elements for pipes and other components.

Figure 3.2: Picture showing an example of a fully assembled cross member.

Figure 3.3: Picture showing the products location on the chassis.

The reason for the choice of product is that it has many variants, it is a complex product with many similar components. The similarity can lead to for example wrong bolt length being chosen leading to assembly problems further down the line. The two variants were selected to be part of the test by the group leader in the factory due to their complexity and differences:

- Single variant

- Double variant

The single variant is a heavy duty variant with one large bogie beam. The double variant has two smaller beams with more complex parts.

The assembly flow for the bogie is divided into 5 stations. Some of the stations contain elements that were excluded from the test due to time and complexity issues in the demonstrator.

- Station 1 - Kitting
  - Pick-by-light kitting, this will not be a part of the test
  - Programming of RCIOM computer unit, this will not be a part of the test
  - Preassembly of consoles
- Station 2 - Tightening
  - Mounting of components and tightening of bolts
- Station 3 and 4 - Cable harness
  - Two stations in parallel because they take twice the time of the other stations
  - Assembly of the cable harness, this will not be a part of the test
  - Mounting of the cable harness
- Station 5 - Valves and tanks
  - Mounting and tightening of valves, ABS/EBS and air tanks

An image of the production flow in the factory can be seen in figure 3.4. The product travels through four unique stations (station three and four are identical but with a slower cycle time).

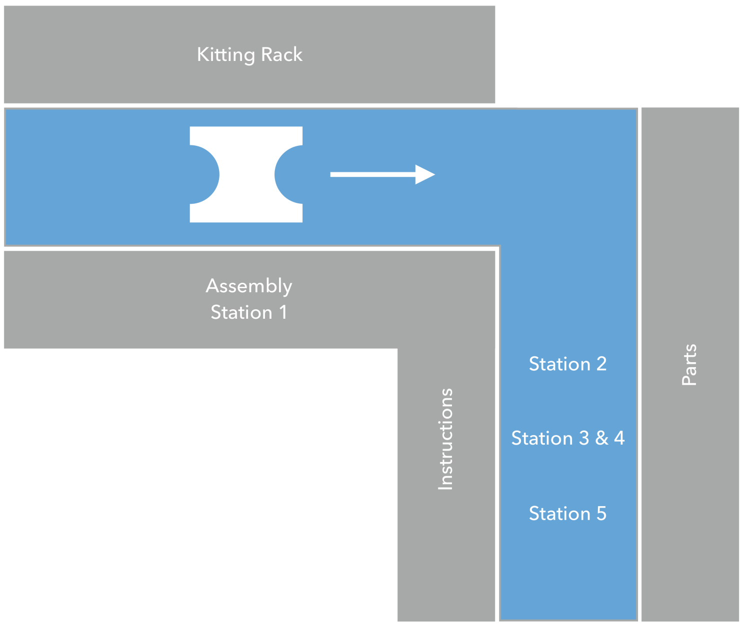


Figure 3.4: Picture showing the current work station flow att Volvo Tuve for the bogie sub-assembly.

3.4 Preparations for tests

A lot of fundamental work was needed to prepare for the operator tests. The main tasks of the preparation are listed below:

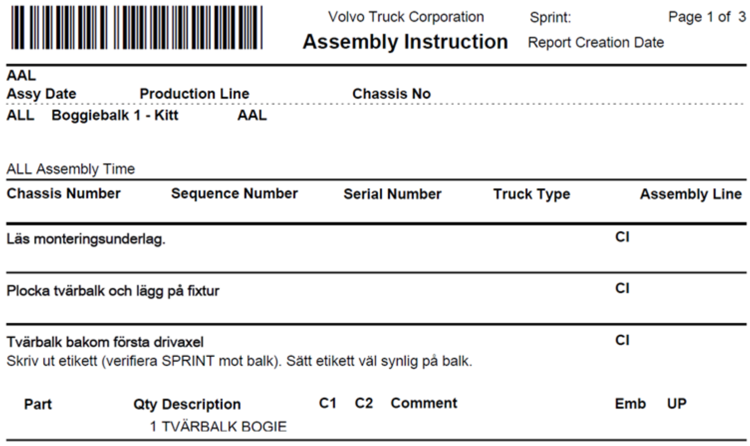
- Create three sets of instructions for two variants.
- Complete the demonstrator and supportive equipment.
- Testing of the two points above.
- Logistics and factory space.
- Make sure there will be real operators available.
- Design of tests, questionnaires and interviews.

3.4.1 Design of instructions

At Volvo today, a system called Sprint is used as the primary assembly instruction. Sprint is basically only a bill of materials (BOM) containing all the components and material used in the assembly procedure. It has been modified to include short comments on positioning and orientation of some parts. It is important to note that these assembly instructions are barely that. It is a part list, not a fully fledged work instruction.

Information that is relevant to technicians is also presented in the instructions, for example, information regarding packaging. Due to the lack of images and detailed instructions in Sprint, the operators develop so-called SOP (Standard Operating Procedure) which contains more detailed instructions and images of how the assembly procedure is conducted. The SOP is mostly used as learning material and when the operators need further support. However, that information is not presented by standard, it has to be retrieved when needed.

In figure 3.5 an example of a Sprint manual can be observed. It has been edited for confidentiality reasons. It is at the bottom of the page, where the name 'TVÄR-BALK BOGIE' appears that all the articles to be assembled are listed. Depending on the number of components, more articles would follow below it. There is also a section for comments, such as positions as well as some other main instructions listed in between the horizontal lines. The rest of the information is not used by the operators[24].



Volvo Truck Corporation | Sprint: | Page 1 of 3

Assembly Instruction | Report Creation Date

AAL

Assy Date **Production Line** **Chassis No**

ALL **Boggiebalk 1 - Kitt** **AAL**

ALL Assembly Time

Chassis Number	Sequence Number	Serial Number	Truck Type	Assembly Line

Läs monteringsunderlag.	CI
Plocka tvärbalk och lägg på fixtur	CI
Tvärbalk bakom första drivaxel Skriv ut etikett (verifiera SPRINT mot balk). Sätt etikett väl synlig på balk.	CI

Part	Qty	Description	C1	C2	Comment	Emb	UP
	1	TVÄRBALK BOGIE					

Figure 3.5: Example of current Sprint manual used at Volvo

The platform for instructions that was used in this project is called Casat, developed by MVV International which is a consultancy company which also develops software and other technical solutions located in Vara, Sweden. It is one of few available softwares for this purpose on the market and is used at Chalmers in several projects. The software also has the essential ability to connect to the Atlas Copco nut runner and other tools that might be necessary or supports the assembly process. For example, scanning of critical articles before it allows for progression. The software had some constraints due to it still being in development which forced some limitations of the design of the instructions.

The instructions was designed in four levels of detail. Since the idea is that an individual is best supported by their own type of instruction (a novice may need more detailed instructions than an expert) several instructions will be made to accommodate operators of different experience level.

The four levels are listed and described below, the higher the level, the more detailed the instructions will be:

- 1. As Is/Sprint
- 2. Basic
- 3. Dynamic Experienced
- 4. Dynamic Novice

The first one is a Sprint manual, the same instruction used today but with minor edits to make it correspond to the work being done in the demonstrator.

The second level is a basic instruction in Casat only containing the same information that is presented in Sprint, but with the difference of only presenting necessary information and not any of the redundant, incorrect and duplicate information present in Sprint. It also has the benefit of just showing the current assembly step. Further, it also has the ability to count the number of bolts tightened in an assembly step to reduce the risk of errors by preventing the operator from advancing in the instructions before all tasks are performed. The purpose of the systems design is to support experts and intermediate operators with quality control, more natural division of work and more comfortable information acquisition.

The third level contains heavily modified instructions with detailed images. The amount of text is also higher, giving instructions and reminders to do critical steps. The purpose of this version is to support expert, intermediate and novice builders to a degree. It will contain images for quick information search with text backing up the less experienced operator.

The fourth level contains even more images and more detailed text instructions. The purpose of the fourth level instruction is such that anyone with minimal knowledge of the product can assemble it.

The purpose of these different levels of details is to identify which information is used, by whom (level of skill of the operator) and how. It is also supposed to reveal what the operators appreciate with the different instructions depending on their own level of skill and technological experience. The time and quality of assembly was also assessed. The hypothesis is that an expert needs less support than a novice, which might annoy the more experienced user. For a novice, such a mismatch might lead to a lack of assembly information necessary for completion of an assembly.

A lot of time was spent iterating, ensuring that the instructions were easy to understand and that they were uniform between variants, stations, instructions detail level and in between activities. Due to limitations of the software, some ideas could not be realized. The end result was however satisfactory enough for the testing. It was of high importance that the instructions were cognitive and intuitive sufficient enough that the operators do not struggle with its usage and therefore gets slowed down by them.

The images were edited to highlight the components being worked on to simplify the information search for the operator.

3.4.2 Demonstrator

To conduct tests with operators, a modular assembly station was needed to allow for a realistic assembly scenario. The modularity refers to the ability to perform a test in different assembly stations in the same area. The equipment and material needed for four different assembly procedures had to be available at all times. The demonstrator was partially built in a previous course, so some of the main legwork is already performed, however many changes and optimization to the tooling, placement/tool holder, positioning of material, button and monitor was necessary. Some limitations were made in relations to the real bogie assembly line, for example, the cable harness assembly and the kitting process is already completed, mainly due to equipment and time limitations.

3.5 Qualitative research

The qualitative data was collected through interviews and observations. The purpose is to get a more open view on the operators' opinions and give insight into the reasons behind them.

3.5.1 Interviews

To gather information about the operators' perception of the different types of instructional information detail levels, interviews were conducted with all operators participating in the tests. The interviews was semi-structured, meaning that several areas of interest are listed and discussed with the interviewees, this gave the interviewee an opportunity to shape their answers which may give more information regarding the subject, compared to if a well-structured interview or if closed questions are used[23].

The areas of interest in the semi-structured interview are linked to the intrinsic and extrinsic dimensions previously stated.

The interviews are a way to support the finding of the quantitative data and to further identify what the operators want and expect from an assembly instruction. For the interview, a set of questions/topics was drafted that were used to lead the interview. However, much emphasis was put on getting a discussion with the operators to yield honest, reflective and open answers.

The interviews were held in Swedish as it is the native language of all the operators. A translated version of the questions/topics is presented below.

- Questions about Sprint
  - What information they use in Sprint
  - What they miss in Sprint
  - Problems with Sprint
  - How much they use Sprint
  - What is good with Sprint
- Pros and Cons they see with digital instructions
- Their perception of the system they tested
- Perception of the Atlas Copco feedback/built-in quality control
- Other ideas they might have

Even though these topics are rather open, all the interviews were focused on making sure that the operators discuss the same key points.

3.5.2 Observations

The observations are things that were noticed during the experiments, both from operators as well as experiment supervisors. These can be in many different categories such as problems with the demonstrator/instructions, mistakes made by the operators or comments made by the operator. A form of protocol was also used to check for repeated error both in the Assembly process as well as faults in the demonstrator/digital instructions. These observations will then be discussed during interviews with the operators.

3.6 Quantitative research

A quantitative data collection was done in parallel with the qualitative according to the mixed method research methodology[21]. The purpose was to get numerical data that is easy to interpret, especially when it is merged and supported by the qualitative data. There was some obvious limitations to the quantitative data sample size since there was a limit in time and available of operators in the plant. It was however still possible to identify trends.

3.6.1 Statistical data

Using the statistical analysis software JMP, a Design of Experiments was performed to identify variations between the operators' skill level, their given instructional information level and responses in terms of cycle time and quality level. A design of experiments is a method of predicting the outcome of a test by changing the input preconditions, in this experiment, a full factorial design was used which means that all possible combinations of input preconditions were tested. In addition, to being able to predict the outcome, it is also possible to identify which input variables that have the most significant effect on the outcome. Two different input factors were varied; Operator skill level and Instructional information level as previously described.

3.6.2 Questionnaires

All operators that participated in the tests were given a questionnaire after their test. The questions in the questionnaire were designed to identify eventual problems linked to intrinsic and extrinsic instructional information quality. The operators' individual experience of technology was also investigated in the questionnaire to find a possible correlation between attitude towards technology and operators perception of digital instructions. The questionnaire was also used to compare the current instructions with the instructions to be created for the tests.

The questionnaire was created from the framework of success determinants by DeLone and Mclean[7][5]. It was then adapted to ensure that the questions would yield sufficient answers. These determinants are listed in chapter 2.2. The determinants are useful as they cover all essential areas that can affect the IS success and therefore allow the questions in the questionnaire to extract answers that cover these topics.

The following main categories are included in the questionnaire:

- Experience and habits of digital media
- Usage and opinions about the current instructions
- Image content of test instructions
- Text content of test instructions
- Layout of test instructions
- Current instructions versus test instructions

Since all the operators' native language is Swedish, the questions were written in Swedish as well. The purpose of the questions was to yield quantitative data that can be analyzed to allow for identification of trends and gauge how positive or negative the operators are to their current instructional system and alternative future system. It was also compared to and supported by other collected data.

Since the operators were of different experience levels, it was possible to see how much support an operator wants in their assembly process depending on their experience. Also, depending on which instruction type that is used, the questionnaire will change the possible answers so that an operator that do not have any images in their instruction will have no questions regarding that subject. The logic behind the questionnaire was managed with the web platform for questionnaire called Typeform. Therefore some data will be blank for some questions/operators. The questions that will be asked are presented below, translated into English and divided into categories.

3.6.2.1 Detailed questionnaire

A more detailed breakdown of the questionnaire will be presented here.

First, a few questions regarding instructions and the operator are asked:

- Instruction type
- Experience of assembling the product
- Age

Use of digital media to gauge technological know-how. Some questions are multiple answers and some are grading scales.

- Use of computers/smartphones/tablets
- Use of digital services (eg. music, internet, navigation)
- Preferred information channel of news (eg. newspaper vs internet)
- Perceived experience of using the technology (hard vs easy)
- Fixing technological problems with phone/computer (Do they Google, ask someone else or trial and error)
- Acceptance/confidence in using new technology

Questions regarding their current instructional system, Sprint and if it supports their work.

- If they use Sprint
- If they consider Sprint to support their work
- If Sprint contains sufficient information
- If Sprint contains correct information
- If Sprint has unnecessary information
- If they believe errors in Sprint are fixed
- If their requests to changes in Sprint are heard
- If they believe that they would use Sprint more if it was more correct and efficient

Questions regarding their perception of the images in the dynamic instructions. The amount differed in the different instruction versions. These questions will be helpful to gauge if the instructions/images created were considered useful.

- Perception of the number of images
- Perception of image quality
- Did the images focus on the correct things

Questions regarding the text. The amount and the level of details differ a lot between the versions.

- Perception of the amount of text
- Perception of sentences/language used in the text

Questions regarding layout and if they considered the system user-friendly.

- Perception of the navigation in the digital system
- If the navigation worked as expected

Questions regarding their perception of digital instructions in comparison to Sprint.

- Which they consider to be most user-friendly
- Which instruction type they believe suits an experienced operator the most
- Which instruction type they believe would reduce the errors they make the most
- Which instruction type they believe suits a novice operator the most
- Their willingness to contribute and affect the instructions in a future scenario

Most of the questions were designed to force the operators to answer since it's believed that all operators should have an opinion about the area of interest. In practice, this means that answers like "don't know" or "no opinion" are left out on purpose. One significant disadvantage of forcing a choice is that operators that might be unsure of their opinion tend to select a rating in the middle of the scale, which will make the mean value of the questionnaire closer to the center of the scale[25].

The scales are also balanced, meaning that there's an equal number of positive choices and negative choices. Unbalanced scales will provoke a biased answer and is not favourable in this analysis[25].

4 Results

This chapter presents the practical aspects of the project such as the Casat instructions and the demonstrator. It also presents the findings of the data collections and analysis.

4.1 Instructions in Casat

The three different versions of information detail that were created in the software Casat are presented below. Casat is as mentioned a platform developed by MVV for use as an Enterprise execution system. It has many functions, but the primary functions used in this thesis were digital instructions and tool integration. Casat is variant driven, that means that publishing instructions for variants with minor differences are an easy task. However, in this thesis, the two variants were created entirely separate.

There are two variants of each instruction level the double and single bogie. A couple of images will now guide the reader through the Casat interface. Due to the aspect ratio of the monitor used to capture these images, some information was not shown in one image. Refer to figure 4.1 on the following page together with the list below for information of different areas. Numbers are marked in the images and correspond to the numbers in the list.

1. Presents the main Activity, the list allows for navigation to the previous and next step in the assembly. The symbols show the number of steps, quality checks, parts and tools used in the activity.
2. Allows for the customization of layout and font size. On a touchscreen it also possible to pinch-to-zoom.
3. The different steps of the activity. Can contain images, and three different instructional texts of different importance per activity. The images can be pressed to zoom. It is also possible to have a title image at the top of the screen.
4. Goes back to the main menu which contains the station view, where the product/order the operator is working on and the once waiting in the queue can be viewed.
5. Next activity. This is has a complementary physical button, both wired and wireless that the operators can press. This button will not allow the operator to progress if the system has not received all the quality checks from the tool.
6. List of articles and tools.

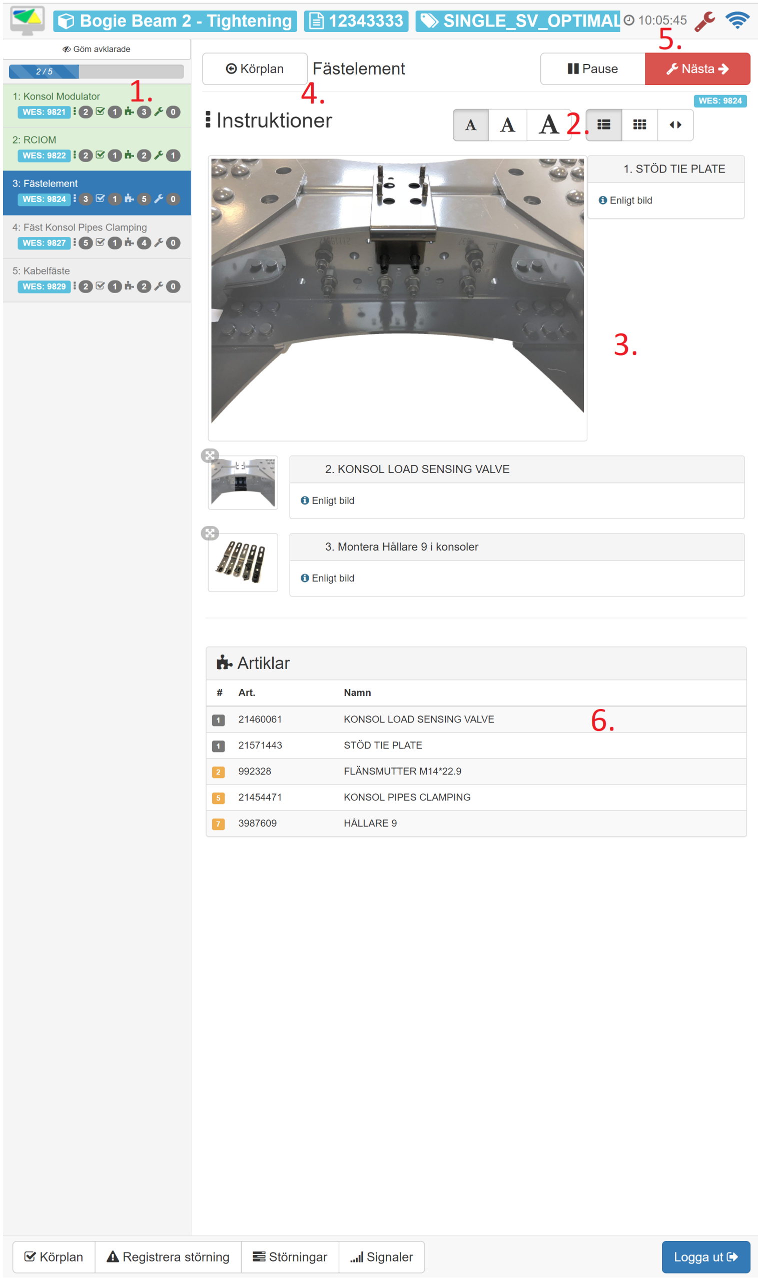


Figure 4.1: Dynamic experienced variant without activity list.

Some features that were wanted was not possible to achieve in Casat since the software is still work in progress, but the results are sufficient for the tests. The three variants are presented below. The same activity is shown in all variants to visualize the differences between them.

The Basic variant contains only small differences from the Sprint/As is material. The most important differences is that the Basic variant contains built in quality control supported by Casat. The tool used for tightening bolts both counts and verifies torque used to ensure that all bolts are there and correctly tightened. It also presents only the needed information for the operator and not all the repeated and unnecessary information that Sprint contains[24]. It presents the information only when it is needed and when an operator completes a step, it is hidden. It does however not feature any additional information than the Sprint version, only presentation and readability is improved. This version is aimed at expert or experienced intermediate operators that know the tasks, parts and variants well. It is only there to support their quality and improve their information search. See figure 4.2 for an example instruction.

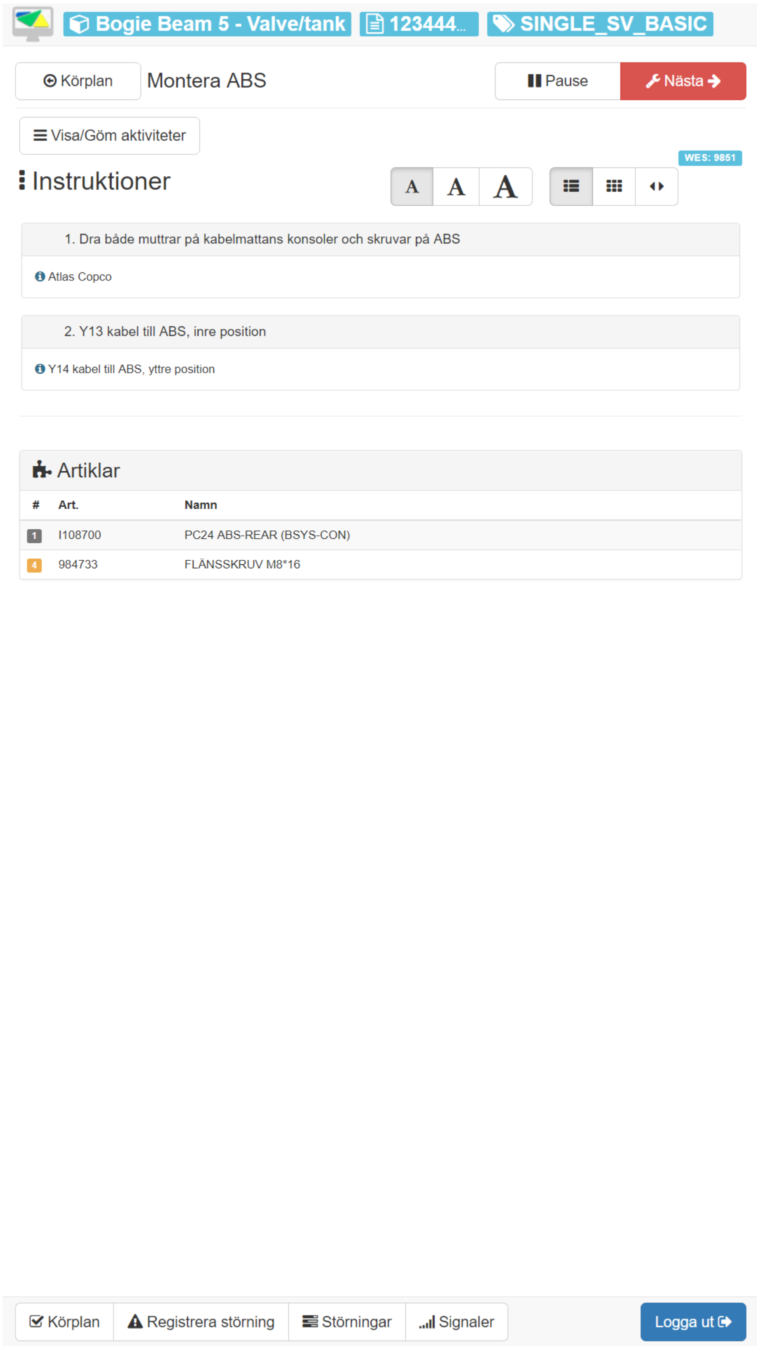


Figure 4.2: Basic variant

The Dynamic experienced variant contains additional text outside that which is presented in Sprint. It also contains images with transparent backgrounds to reduce the number of distractions. Some images also include blurred and highlighted areas to further improve understandably and readability. Where it is appropriate, there is also text and markings in the images of positions and bolt lengths to reduce the amount of reading in the text. The text in the instructions assumes that the operator has previous experience with the task. However, the images fill the gap in knowledge if a novice operator would use the instruction. Refer to the previous figures **??** and 4.1 for an idea of differences between the versions. The Dynamic experienced was pretended to the operators in the layout pictures in figure 4.3. The reason for this layout is to minimize the number of interactions the operator needs to do. The larger preview images enable the operator to quickly see what there is to be done in the task.

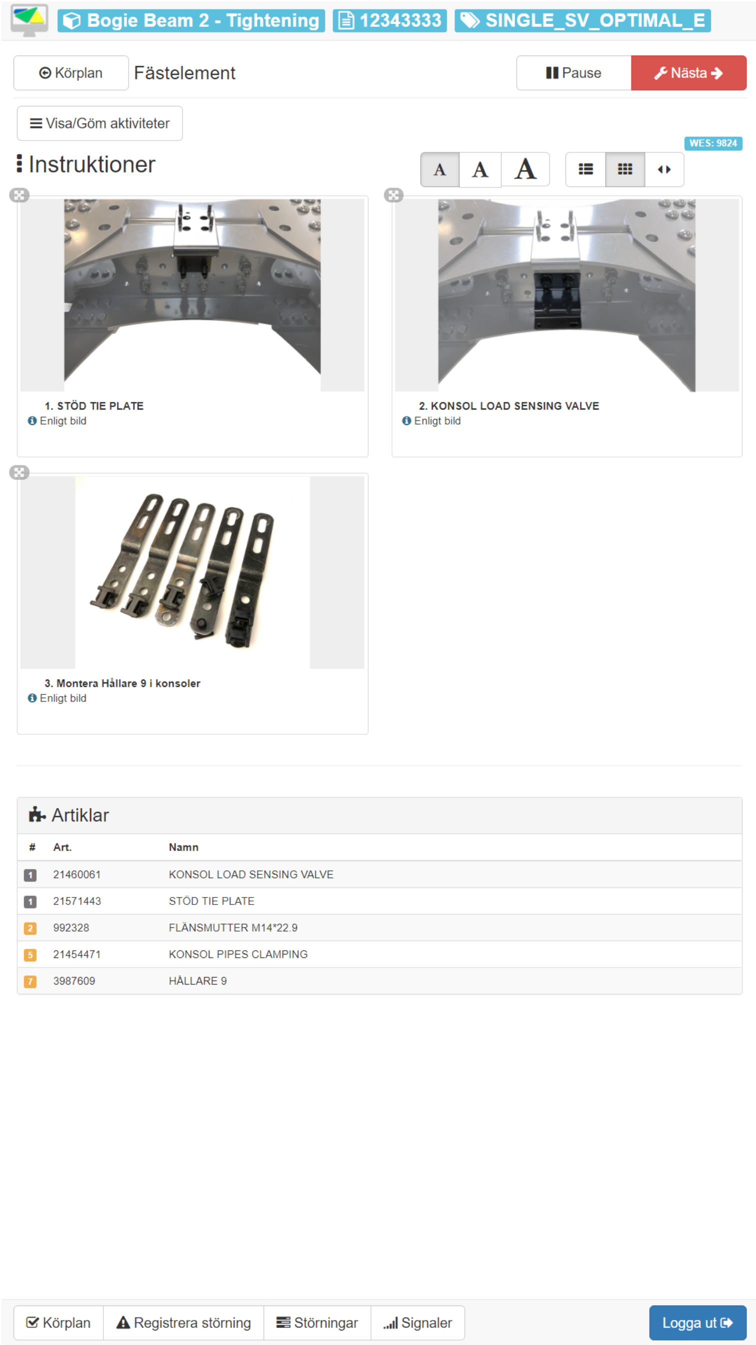


Figure 4.3: Experienced instruction with a different layout

The Dynamic Novice variant contains the same basic information and images as the Dynamic Experienced, but with a few more pictures and steps. Mainly it includes a lot more text if the operator needs it. Refer to figure 4.4, compare the amount of text in between the versions. Some instructions have a more significant difference in text amount than others.

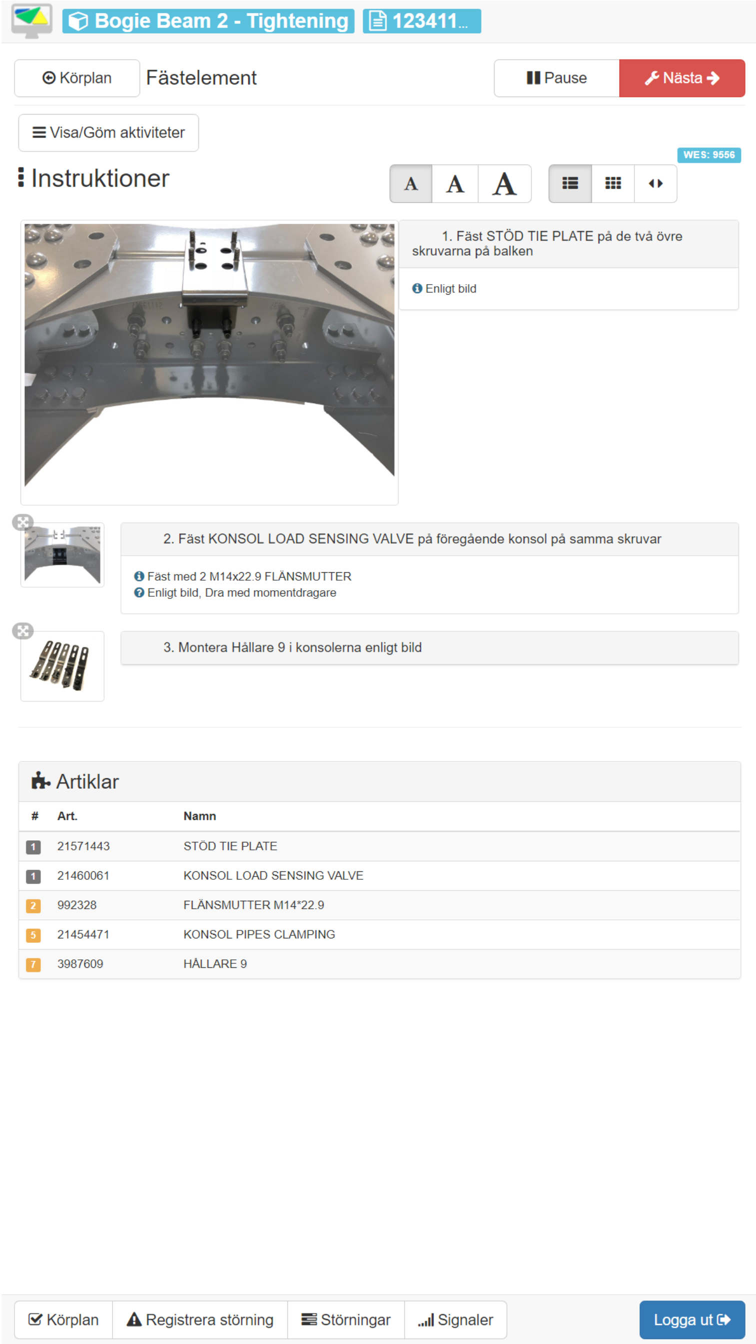


Figure 4.4: Dynamic novice variant

The instructions were not created in cooperation with operators due to limitations. It was a logical and iterative process that used mainly the works by Mattsson[11] and Fast-Berglund and Blom[12].

4.2 Demonstrator

The demonstrator contains all the necessary parts to simulate the real world. As mentioned in chapter 3.4.2 it is not possible to have all four stations in line like in the real assembly line because of space and equipment limitations. Instead, simplifications had to be made. These simplifications mean that the work of all the stations is carried out in the same spot with the same equipment. The interviews verified that the usability of the demonstrator met the demands of the operators.

The Demonstrator is built up by several parts. The material, both consumables and articles are presented in four locations. A kitting box which contains consoles that are used in the first station. Some consumable material is stored on a workbench where assembly work takes place. The material is mostly nuts, screws, washers and zip ties. A material rack with the bulk material, such as larger screws and nuts that are used in the tightening stage of the process. Lastly, the material for the later stations is stored in boxes on a cart on the opposite side of the bogie fixture. The reason for this layout is that it resembles the real assembly environment and allows for the storage of articles so that the material for the same station is stored in the same location. It is worth noting that the presentation of material is not optimal, due to space limitations, but it is functional enough to conduct the testing.

The nut runner used in the experiments was integrated with the Casat and used to ensure that all bolts and nuts are tightened, preventing the operator to move forward before a step was completed.

The monitor was placed such as it was accessible from all areas of operations. It was mounted on a flexible arm which allowed it to be moved in all directions to fit the operator both in length and positioning. However, when working on some positions of the bogie, the monitor may be either too far away or behind the operator, but that was hard to avoid in this scenario without mounting it from the roof. There was also a button which was used for moving through the assembly instructions located on the workbench. A wireless alternative was also developed.

In image 4.5 an overview of the demonstrator is depicted.

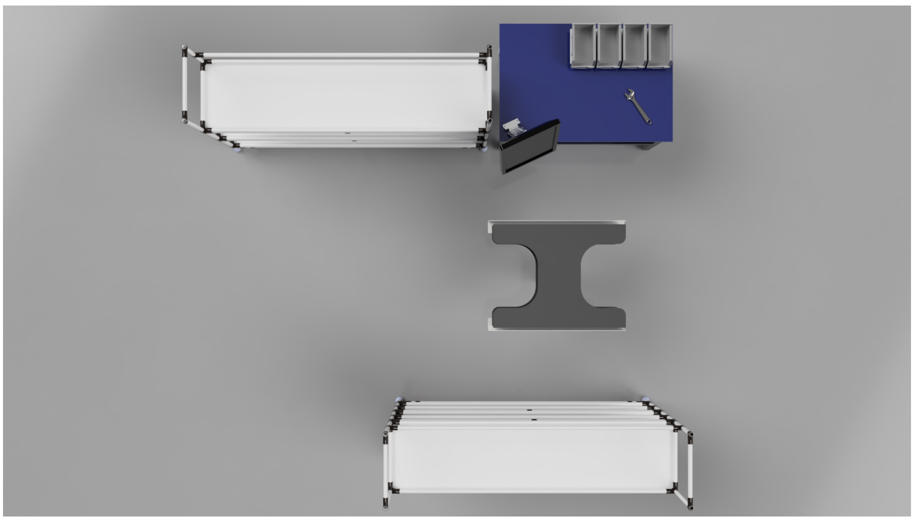


Figure 4.5: Overview of demonstrator.

4.3 Operators and Sprint

The data collected through the different data collection methods have been used to identify and categorize how the current instructions are used and its eventual problems. The framework created by Haug[4] is used to categorize the eventual issues into intrinsic and extrinsic informational quality problems.

Inquires were made to establish the current situation at the plant, both through a questionnaire as well as through interviews. This data is presented to visualize what the current problems within the assembly and also hints at what the causes may be. Mainly, it displays to what extension the current instructional material, Sprint, is used as well as why or why not it is used. It will also bring up organizational problems that are potential underlying causes to the reduced confidence in Sprint as a work instruction. It is also important to point out that Sprint is a Bill of Materials rather than an assembly instruction, even though it is viewed and used as such.

A full list of all the data and questions asked can be found in the Appendix A.2, some questions/answers that were considered irrelevant or non-usable is not mentioned in the results chapter.

All operators were asked if they are actively using Sprint as a part of their daily work, though it's important to know that all operators have access to Sprint-instructions. As visualized in figure 4.6, 9 out of 13 operators use Sprint in their daily activities to *some* extent. This may be as little as just checking a production ID or a bolt length.

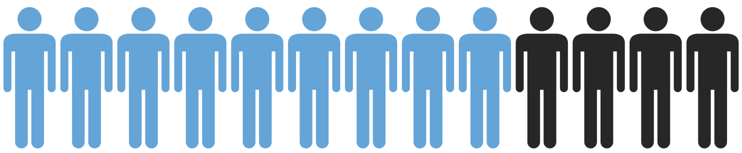


Figure 4.6: 9 out of 13 operators stated that they use Sprint in their daily activities.

From the discussions during the interviews many different viewpoints, ideas and problems were highlighted. It is important to note that the reception and use of Sprint are dependent on which part of the production an operator works, this is due to the different levels of management support Sprint receives on different stations.

For example, at the gearbox assembly station, Sprint is used extensively. The reason for this, according to the operators is that the Sprint is well supported by technicians and contains correct information, which is very critical at the station. At other stations, however, where the operators work from memory and routine rather than from the instructions, Sprint is often outdated and incorrect. From the inquiry of the operators, the reason for this is part of a vicious cycle. Since the operators do not use Sprint, the technicians have no motivation to update the info leading to even lower use of the Sprint. Over a long period, errors and poorly updated information makes the material unusable.

From the interviews it could also be noted that on the driven production line, only one station out of seven even opens the Sprint instructions, the rest goes straight to recycling. They do not have the time nor need to use the material. On the bogie assembly, the use differs a lot between operators and stations. For the assembly of the cable harness, Sprint is very much needed due to many small differences while on the other stations, common knowledge of the components and material is enough to complete the tasks correctly.

The low use of Sprint is certainly not only due to it containing bad information and more based in the fact that the operators learn all the variants they need to handle by memory, making the assembly material redundant. Even though 9/13 operators stated that they use Sprint daily, they do not use it extensively. The more experienced operators only use i to verify small parts of their assembly work. This is sometimes a forced process since on a driven line, time is of the essence, limiting the operators' ability to use the material for fear of running behind.

In table 4.1 the most critical problem areas are presented, they are mentioned more in detail in the following text.

Table 4.1: Critical issues identified regarding the use of Sprint.

Environment	Identified Issues	Consequence
Line	Most of the operators are building from experience rather than instructions.	Easy to miss deviations and rare details.
Line	Balance times are incorrect.	Operators are overloaded. Tasks are unbalanced between stations.
Line	Most stations are throwing away the instructions when they arrive.	Instructions are not used and therefore not updated.
Both	Additional information given orally since Sprint often gives insufficient or wrong information.	Information is not always given to all operators.
Both	Sprint is mainly designed as a BOM not as work instructions	Requires training and teaching to use the instructions.
Bogie	Operators are mainly using sprint to double-check important details.	Easy to miss deviations and rare details.

A reader might believe that the operators working by memory should be a small issue, however, as many interviewees have stated, they often make mistakes due to special orders and deviations from the standard variants. Many operators are used to building the different product variants by observing the incoming material and component, and for these operators, they believe that this is sufficient to build the product and the need for Sprint is experienced as useless.

Another issue with Sprint is that the material is hard to understand and it is, especially for the untrained very hard to search information in it. Beginners need a teacher to help them understand the instructions. It is, however, important to note that some of the more experienced interviewees considered Sprint easy to read and understand but they all agreed that it contains too much irrelevant text and information. This statement is also supported by a previous master thesis that identified that a large part of the Sprint is unused by the operator[24].

When training new operators, they must be taught what information in the Sprint is correct and what is not leading to a very complicated and confusing learning experience for the novice. In connection with this, since some Sprint is not updated nor used, it leads to an incorrect assessment of the amount of work is needed in each station. Another issue with the time balancing is that the technicians do not update the Sprint when extra work is needed on a variant. This means that there is more work to be done on a part than it is displayed in the Sprint, this leads to an overloaded operator.

One thing that operators raised as positive with Sprint is that it allows them to work at their own pace (that is, faster than required) which means that they can accumulate longer cohesive breaks. Such work is not preferred in a production facility but explains some of the operator opinions. The current best work standard is also not in Sprint as the operators do not follow the Sprint work procedure step by step but rather their own, more optimized version.

Several issues are identified in the actual work instructions, the different issues are categorized into five main categories of intrinsic factors. Intrinsic issues are measurable and it's easy to find issues in the work instructions in opposition to extrinsic factors that are more related to operators perception of information. The identified instructional issues are presented in table 4.2

Table 4.2: Identified intrinsic issues.

Intrinsic Factor	**Identified Instructional Issues**
Deficient Information	Lack of assembly instructions. Sprint mostly used as BOM. Tasks are left out. Tasks are listed in wrong stations. Missing articles.
Ambiguous Information	Different positions for the same article.
Unneeded Information	Information about shipping details. Articles that are used in other stations. Information used be technicians.
Incorrect Information	Incorrect length of screws. Incorrect positions. Incorrect balance times.
Too repetitive Information	Articles that is used in other stations.

Data collected through the questionnaire which the operators filled out after the test were mostly regarding extrinsic factors, however, when operators were asked to rate the statement "I believe that Sprint contains correct information", the following result are shown in figure 4.7

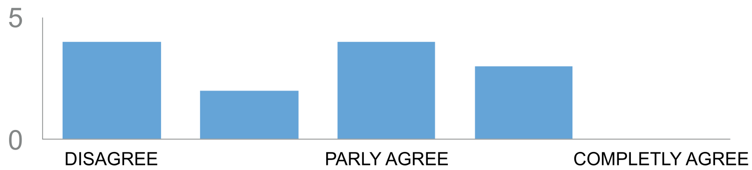


Figure 4.7: Operators perception about correct information in Sprint. (Number of operators)

In opposition to the intrinsic informational issues, several issues were identified that can be linked to the extrinsic informational categories defined by Haug[4]. The issues in 4.3 issues are derived from operator interviews.

Table 4.3: Identified extrinsic issues.

Extrinsic Factor	Identified Issues
Representational Problems	One article may have different names in different stations. Operators states that there not seems to be any standardization in the work instructions.
Unmatched Information	Instructional information is hard to understand. Instructions contains information that is not relevant to assembly work. Instructions contains assembly information about more stations than the actual.
Questionable Information	Operators don't trust instructions since information is not always updated. Operators states that technicians aren't listening and therefore stops to come up with ideas and improvements.

The results in 4.8 were found when operators were asked to rate the statement; "I believe that Sprint contains unnecessary information."

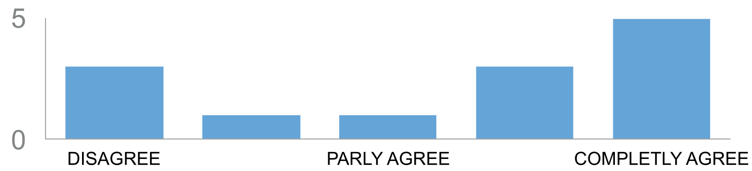


Figure 4.8: Operators perception about unnecessary information in Sprint. (Number of operators)

In addition to the identified issues within the actual work instructions, various problems are defined within the area of service quality. In this report, service quality is about the organizational support towards improving and developing an instructional information system that supports the operators in their daily activities.

All operators that participated in the tests stated that they want to be able to affect their own work instructions, however, when the operators were asked to rate the statement "I feel that I can currently influence the content in Sprint" the following data could be observed. See figure 4.9.

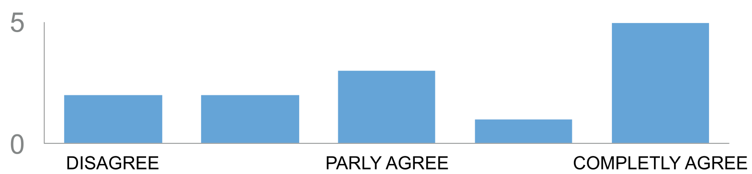


Figure 4.9: Operators perception about their ability to influence Sprint. (Number of operators)

There is a large spread in how much the operators believe they can affect sprint. Many differences are depending on if they work on the production line or in a sub-assembly. Also, a vast majority of the operators also states that errors in Sprint not being corrected in a timely manner.

4.4 Operator attitude toward technology

To gauge the operators' reception to new technology, a set of questions were asked in the questionnaire. The purpose is to reveal if they are more or less open-minded in regards to new technology as well as if they consider themselves proficient in using technology. In extension, it will reveal the possibility that the answers to the other questions may be directly affected by their attitude towards technology.

All of the inquired operators answered that they use frequently use a smartphone/-computer/tablet.

Further, they were asked to note how much and which digital functions they use in their daily lives. The data can be observed in figure 4.10. The operators use a wide array of functions on their phone which hints at their proficiency and preference to using digital services. Same applies to the preferred channel of news. As seen in figure 4.11 a majority of operators preferred to use phones/tablets to receive their news. Multiple answers were allowed. There where a total of 13 operators.

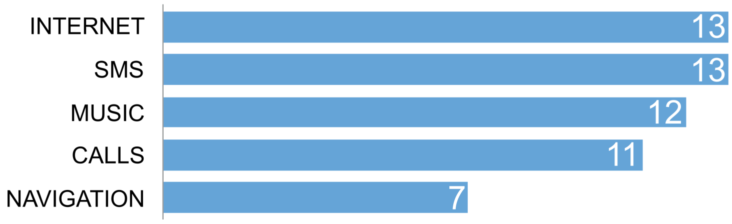


Figure 4.10: What services are you using in your daily life. In number of operators. Multiple answers allowed.

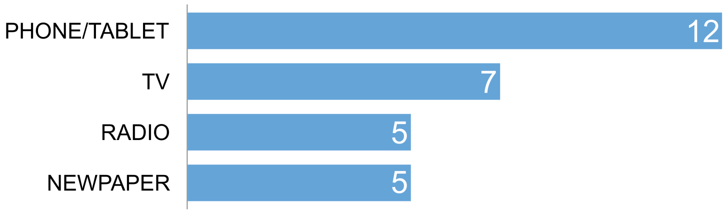


Figure 4.11: Preferred channel to receive daily news. In number of operators. Multiple answers allowed

As for the operators personal experience in using new technology in everyday life, all but one operators considered it easy to use. The final operators considered it as neither easy nor hard to use. Visualized in figure 4.12

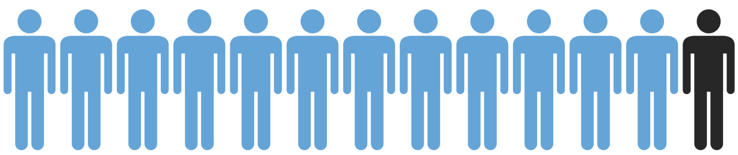


Figure 4.12: Ease of use of new technology.

As seen in the figure 4.13, there is a spread over the proficiency of the operators. However, most of them use either experience to solve a problem or search the internet for information.

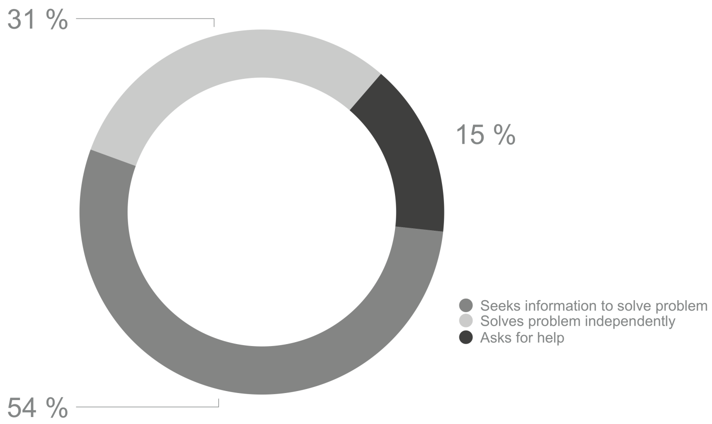


Figure 4.13: If I need help, my first step in troubleshooting is the following:

All the operators either agreed fully or partly to the statement; "I feel confident when using technology I have never used before." The spread is displayed in figure 4.14.

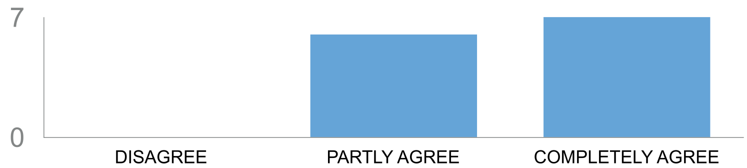


Figure 4.14: Confidence in using new technology. (Number of operators)

The data regarding the users' self-efficacy show that the sample of operators that were participants of the test are all favorable to new technology and are reasonably proficient in their use.

Since the operators generally are positive to technology and consider themselves somewhat confident in its usage it is not possible to identify any trends from their answers regarding the attitude towards technology and technological knowledge in correlation with how they responded regarding their perceived experience in the digital system.

4.5 Analysis of operator test results

During the tests, two types of data were collected, time to assemble as well as a quality check. The data collected is not statistically confident. However, it is a good identifier of trends which can be supported by the stories told by the operators. Since the entire assembly station is new for the operators many time variations can be caused by this inexperience. The same thing applies to the operators being monitored during the test, which can cause stress leading to both shorter assembly times as well as longer due to mistakes. The same thing also applies to the number of errors conducted by the operators.

4.5.1 Time to assemble

The time of assembly was recorded for each operator for each station. The total assembly time was then added together to get a consensus on how fast an operator can work depending on their experience level and their tested instruction. A note on the Novice operators with Sprint and "Basic" instructions is that they received substantial guidance in how to assemble the parts as they had no prior experience with it. The conclusion can be made that an operator with no prior experience of bogie assembly would be able to complete the assembly with the Sprint or "Basic" instruction.

In table 4.4 the times for each operator is displayed, as well as their experience level and instruction type. The columns are Operators skill level, instruction type and time to assemble in seconds.

Table 4.4: Table including all operators and their assembly times. All times are in seconds.

Skill	Information Level	Time (s)
Expert	Dynamic Experienced	1310
Novice	Dynamic Experienced	1305
Novice	Basic	1960
Expert	As is	1020
Intermediate	As is	1020
Intermediate	Basic	1565
Expert	Dynamic Novice	1215
Expert	Basic	1350
Novice	As is	2640
Novice	Dynamic Novice	1950
Intermediate	Dynamic Novice	1665
Intermediate	Dynamic Experienced	1610

This data will be mentioned more in detail in the next few paragraphs. The results from the JMP analysis can be observed in the following figures. Some clear trends can be identified, but with the reservation that the data has too small of a sample size to be statistically confident. For example, it can be seen that a novice with Dynamic Novice instructions was slower than a novice with Dynamic Experienced and only 10 seconds fast than a novice with Basic instructions. The reasons are mainly individual differences between the operators. The operator that used the Basic instruction also received more help, as it would not have been possible to finish the tasks without it.

The first thing observed is that the factor affecting assembly time the most is the skill level of the operator. In figure 4.15 it can be seen that being an expert shortens the time to assemble significantly over an intermediate in the same way that being a Novice lengthens it. The assembly time difference is on average about 6 minutes (360seconds) in both directions.

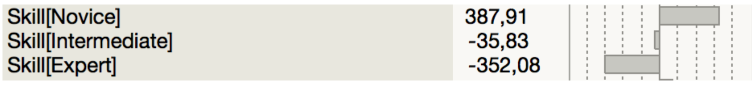


Figure 4.15: Time difference (seconds) depending on skill level, lower is better.

The second observation that is made is that instruction type on average is not a strong indicator of speed. Only the Dynamic Experienced instruction has a small edge in reducing the assembly time on average across all operators and skill levels. Can be seen in figure 4.16.

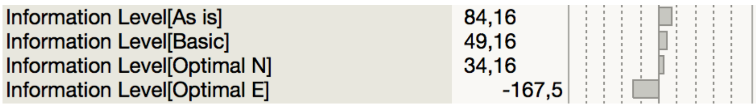


Figure 4.16: Time difference (seconds) depending on instruction type.

It is first when skill level and instruction type is combined that the real benefits of the digital instructions shine through. A novice will shorten their assembly time drastically with more detailed instructions as seen in 4.17. The results hint that the support a novice receives gives direct positive results in their assembly times.

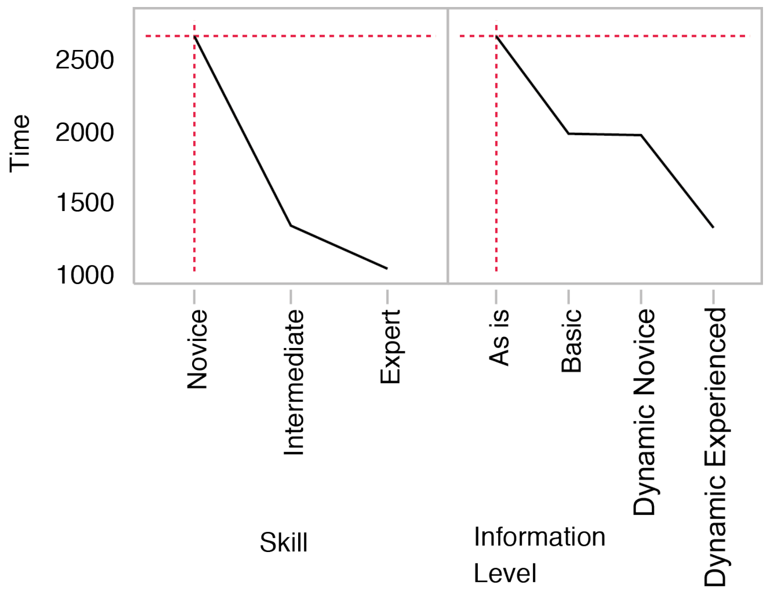


Figure 4.17: Graph displaying assembly times in seconds. The graph to the right shows the assembly times for a novice operator depending in information level.

An intermediate operator benefited the most by Sprint as they need minimal support, so in they were generally only slowed down by the more detailed types. This trend can be seen in figure 4.18. The reason for this is that they only need minimal support and that the detailed instructions crave too much attention in their current versions. Other benefits will be detailed in the next chapter regarding quality.

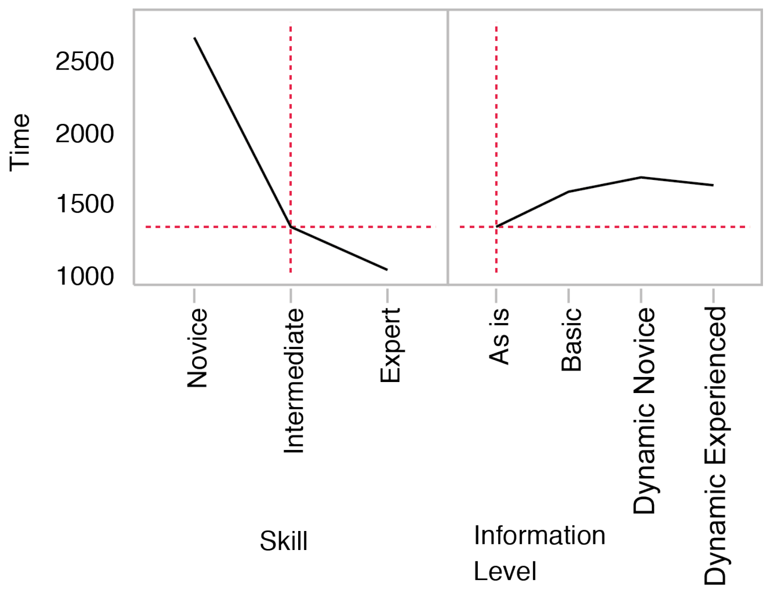


Figure 4.18: Graph displaying Intermediate assembly times in seconds.

Same applies to the experts, they are mostly unaffected by which type he or she uses, but they are quickest with Sprint. Mostly due to them not being hindered by a system forcing them to perform extra work. Extra work in terms of using the touchscreen to advance between tasks, confirming steps, etc. See figure 4.19. The expert using Sprint did not use the work material at any point, it was assembled entirely by memory.

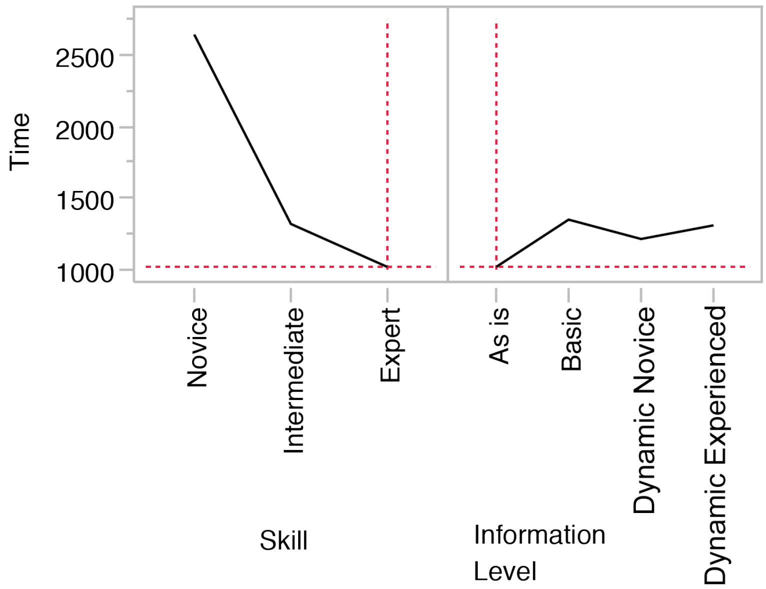


Figure 4.19: Graph displaying assembly times in seconds. The graph to the right shows the assembly times for an expert operator depending in information level.

4.5.2 Assembly quality

The same procedure was used for quality errors in the assembly. The errors performed by the operators were noted during the process as well as during the disassembly to verify that the bogie was assembled correctly. The errors were categorized into two parts, minor and major errors. Minor errors mean things that are easy to fix or does not have an impact on the function of the product, for example, a bolt that is too long but do not disturb any other part. Major errors, on the other hand, are more time consuming, hard to detect or will affect other assembly steps negatively if it is not fixed. Major errors were weighted as having the same value as two minor errors when entered into JMP to generate statistics.

From the JMP model it can be derived that novices and perform significantly fewer errors if they are supported by a more detailed instruction. The reduced amount of errors for better instructions is very understandable since they have no prior experience with the bogie assembly. The same observation can be applied for both intermediate and expert operators, a more detailed instruction reduces the number of errors they make. A reservation has to be made here that both due to the small sample size and that the fact that the operators are observed may affect their quality performance. As seen in figure 4.20 operators reduce their errors as their experience level increases and if they receive other instructions than As Is/Sprint.

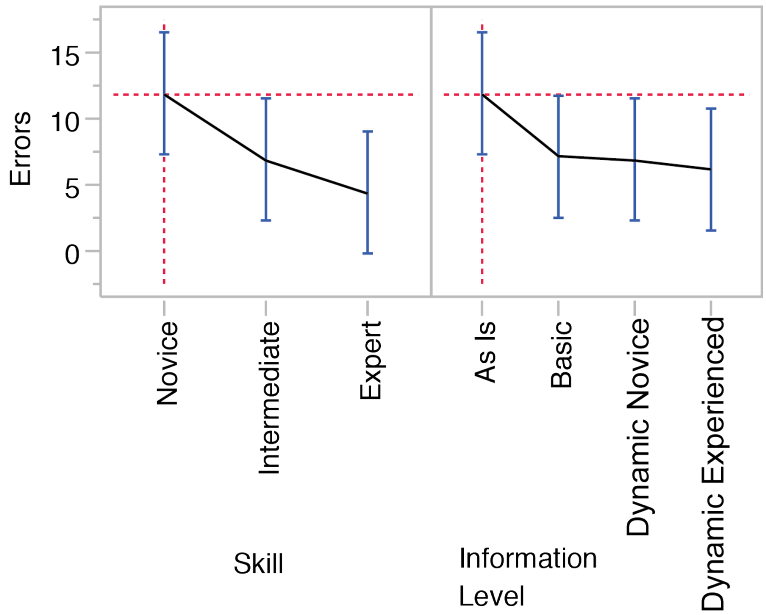


Figure 4.20: Graph displaying amount of errors dependant on skill level and instruction type. The errors are weighted depending on how critical they are. Average, max and min values are shown for the operators.

4.5.3 Operators and the demonstrator

To pinpoint the shortcomings and what could have been prepared better in the demonstrator and instructions a set of questions were asked both in the questionnaire as well as in the interviews.

As seen in figure 4.21 there is a spread of if the operators wanted more or less images. Since Dynamic Novice and Dynamic Experienced contain basically the same amount of images, the responses did not differ significantly between the versions. However, it can be observed that more experienced operators generally want fewer images and novices want more. Though it is noteworthy that 5 people considered the number of images to be good, whether or not they are expert, intermediates or novices.

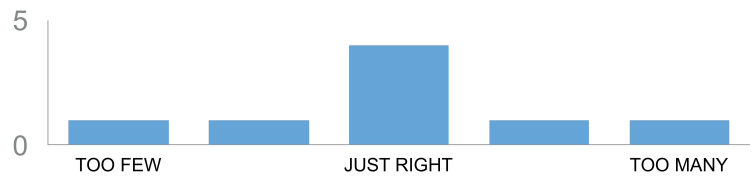


Figure 4.21: Operator answers in regards to the question (Number of operators): I think the amount of images were:

The quality of the images was also well received as shown in figure 4.22

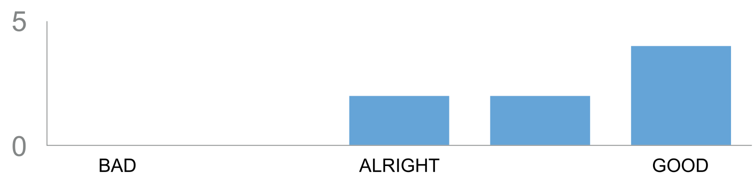


Figure 4.22: Operator answers in regards to the question (Number of operators): I perceived the image quality as:

The causes behind the lower scores are that some operators would have liked more steps per images as well as more supporting texts/markings/arrows in the pictures. This is a very noteworthy request as it shows that operators should be included in the creation of the instructions to optimize them. The use of arrows and markings was also mentioned by Mattsson[11], however the the testing was already completed before it was noticed. The engineers can not know exactly what is preferred by the operators, a dialog must be held between them.

As for the focus on the images following responses could be observed, figure 4.23

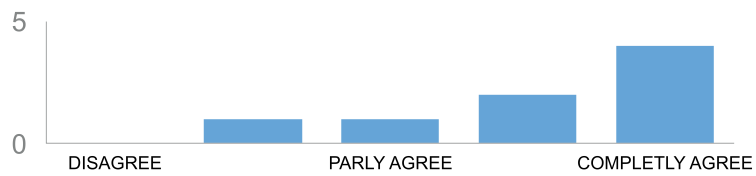


Figure 4.23: Operator answers in regards to the question (Number of operators): I perceived that the images focuses on the correct things:

The lower scores in 4.23 are from a novice as well as from an intermediate that thought that it was hard to distinguish some orientations from the images, this was also mentioned by some of the people that gave a higher score.

The amount of text was well received by all operators, independent of which version they had. Only on operator stated that it was to much text, this was a novice operator on a Dynamic Novice instruction. He mostly used the images as support for his assembly.

Same questions were asked regarding the wording used in the instructions, all operators considered them to be good enough or easy to understand.

Two questions were also regarding the experience of the navigation, figure 4.24 in the menus as well if the interface responded as expected, figure 4.25

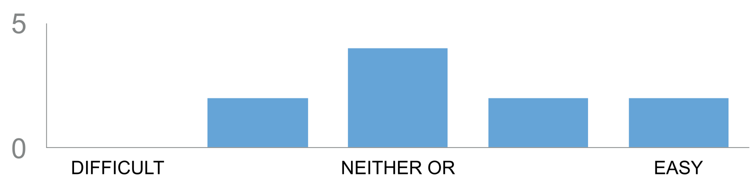


Figure 4.24: Operator answers in regards to the question (Number of operators): Experience of the interface in Casat.

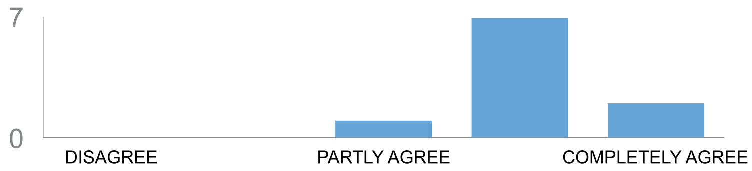


Figure 4.25: Operator answers in regards to the question (Number of operators): Navigation in the menus worked as i expected:

The overall impression is that the navigation in Casat was simple to understand and intuitive to use.

Through the interviews, some investigation was done in regards to what the operators could want and their acceptance of the technology. The general consensus is that having the possibility to customize the instructions depending on preferences and skill is a very good thing. However, this was not tested entirely in the demonstrator and operator tests and will need further testing. They also want clearer instructions and all operators believe that a combination of images and text is a better way of presenting instructional information rather than only using text as in the current Sprint instructions. Even if images are missing in the current instructions, they are used during training in their learning material, the SOP.

During the operator tests, the majority of operators that tested instructions with images stated that the number of images in the instructions was "just right" and none of the operators thought that the image quality was bad.

All operators believe that the digital instructions they tested would potentially reduce the number of errors produced during assembly work, all operators also believe that the digital instructions are more user-friendly than Sprint.

The operators were also asked which type of instruction that they think would be best for an operator depending on skill. Nine out of ten operators believed that digital instructions would be best for a novice operator, visualized in figure 4.26. Just over 50% thought that the digital instructions would be best for an expert operator.

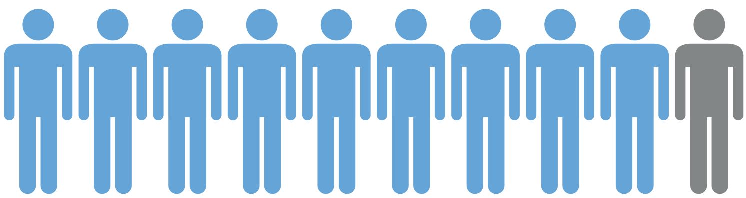


Figure 4.26: 9 out of 10 operators belives that digital instructions would be best for a novice operator.

The different representational features included in the test instructions that were most appreciated by the operators were;

- Images in combination with text.
- Large screen that displays information.

- Feedback from electric torque-wrench in the form of sound and display.
- Built-in quality control.

Depending on their workstation, line vs preassembly, the preferences to how the information should be presented differs. On the moving line, it would be preferred to have one large screen or a portable tablet/phone displaying the most important information such as special orders and deviances. At the pre-assembly stations, having stationary computer monitors is believed to work.

Some operators had ideas of future features that possibly would support their work:

- Animations in combination with images.
- Sound or voice support.
- Color-coding in images.
- Smart-watch or tablet.

The most important thing for the operators is that it supports their work, not hinders it which it could do if implemented poorly. Some operators believes that they would be fine with only being notified on special orders, as they do not need further support.

The operators that were interviewed are overall very positive to technology. Many mentioned the ability to have smartwatches/tablets and sound to supports their work as positive ideas.

The operators that tried out the digital instructions mentioned a few things that they would love to see but was not included in the test. These things were animations (to easily display how an operation is done), more steps per image (fewer steps overall) and more color/text in the images to allow them to focus more on the images than the text in the instructions.

5
Discussion

This chapter will present the authors' thoughts and discussion about the findings and data that previously have been identified and analyzed. The research questions stated in chapter 1.2 are discussed, different limitations that were discovered during the project are highlighted and further work is discussed.

5.1 Operator opinions and reception of the tests

The overall reception of the demonstrator and the instructions were very positive. The operators thought that the demonstrator served it's purpose as being a substitute for their real station and it should therefore not affect their opinions regarding the usability of the instructions.

From the interviews and questionnaires, it could be gathered that more information, especially in the form of images is well received by operators. They all stated that the images were very helpful and increased the speed at which they could search for information regarding what they were supposed to do. The use of the text was also very varied. Experts generally only used the name of the activity, image and article list to assemble the product, while the less experienced operators had to use the text more often. The operators also had a lot of input on improvement ideas such as color coding and arrows in the images to further improve the cognitive support. This is something that should have already been added during the design phase, especially due to it being mentioned in the Design principles For Information Presentation (DFIP) by Mattsson[11]. The DFIP should be used more thoroughly together with closer collaboration with the operators in future work.

All the operators believe that a proper implementation of a dynamic digital instructions system would be an improvement over the current. It was discussed during the interviews about how a future scenario could look. That an operator would be able to control the amount of information, feedback and support they received from their instructions. They would also be able to have more involvement in the creation and editing of the instructions. Another topic was the interest in the technological accessories that could be potentially used, such as smart watches or mobile tablets. All the operators agreed that these things were good ideas that could work with proper implementation, which is in line with what the previous master[24] mentioned in their focus areas and shows that there is support for it from the operators.

As for the instructions, they were considered easy to navigate, easy to understand and intuitive to use, it is, however, important to note that the operators that performed the test are positive to new technology and rather competent in its usage.

So we have to reserve ourselves to the possibility that the system is hard to understand for someone less technology inclined. As DeLone and Mclean[5] state, the importance of the user of a system and their previous knowledge and interests. They conclude that the characteristics of the user: attitudes toward technology, technology experience, and self-efficacy are essential in determining the success of an Information System. They do however point out that training, as part of the management and organizational support can overcome the lack of knowledge and attitude from an individual.

It is fascinating that all the operators of this test were positive and engaging operators, worth noting is that the operators were volunteers and therefore possibly more likely to be interested in user involvement and more favorable to the idea of change. User involvement is as mentioned a key indicator to success[5] however it can not be assumed that the entire pool of workers will have the same opinion as this small, potentially biased sample. A broader inquiry regarding the reception of a new system may be needed to evaluate how well received it will be.

5.2 Performance results

The data collected during the tests for quality and time to assemble showed that the operators performed better if they are supported by a higher level of instructions. For novices, there is a remarkable gain in time when they received detailed instructions. An important note here is that no novice would be able to completely assemble the product with the As Is/Sprint or Basic instruction without supervisor assistance. The current system, sprint, as mentioned is barely even an assembly instruction, it is rather a bill of materials. Sprint can not practically be viewed upon as a assembly instruction as it does not contain instruction on how to assemble, only parts and positions. This was reflected in the novices inability to complete the task even though they knew how to read Sprint. These versions expect the operator to have more than basic knowledge of the product. They could however efficiently and without support from supervisors assemble it with minimal errors with the higher level instructions.

A very interesting aspect is that a novice, who has never assembled a bogie crossbeam assembly before could complete some steps faster than an expert. The reason for this was that the novice operator received an image that depicted all the information in an easy to grasp way. The expert operator that was using the basic version had to read complicated and hard to interpret. This is especially interesting as the expert operator knows how to read the instructions, but it still took a long time to withdraw the information from the instructions. There was also an outlier, a very experienced operator could assemble the entire bogie correctly from just reading the chassis number.

The more experienced operators performed well with the Sprint instructions, even better than with the digital versions. The reason for this is that they know the operations by memory and that they were slowed down by having to verify many of the steps. They said that they would have preferred to have more instructions per step, reducing the amount of interaction they would have to do. This would be the purpose of full implementation of dynamic instructions.

As for the quality aspect, only improvements could be observed. It improved the quality for all operators by having a higher level of quality control. A more experienced operator also performed fewer errors. Another advantage of a digital system is that scanning can be used to confirm that the correct item is attached to the correct product when there is ambiguousness between similar articles.

5.3 Prerequisites for a successful implementation

Dynamic digital instructions such as the tool Casat have some prerequisites for successful implementation same as any other information system. [5]. The determinants mentioned in chapter 2.2 are key for this. From the organizational standpoint, it is important that the support flows from the top. The management needs to support the implementation to ensure its usage. The operators need to be involved in the discussion and they need to participate and help shape their own information system. Another key determinant is the attitude towards technology by the operators[7]. In these tests, the differences in the reception of the digital system could not be measured since all the operators had a good attitude towards technology and at the minimum a decent self-efficacy and technological experience. Further studies with wider sample size are needed to evaluate this properly. All Operators in disregard to age and experience believed that the navigation and interface were easy to understand and cognitive, so the assumption is that any user with proper training should be able to become proficient in its usage.[5]

The implementation of dynamic digital instructions also requires a well connected and functioning IT system that allows communication across many different systems. The information system needs to be able to collect images of 3D renders (CAD-Models) to insert into the instructions since capturing photos of all necessary assembly steps for all required variants is too impractical. It also has to communicate with the designers of the variants so that any bill of material generated there automatically can create a complete an instruction. The key is that the systems need to be responsible for automatically doing many of these things as there is no time in a variant driven industry to create these instructions manually.

As the instructional information systems change towards a more digital and complex system, it is expected that job skills will change as well. The educational system and labor market need to change to maintain a workforce that is adapting to the change towards Industry 4.0. The main areas in the 4.0 that are touched upon by this implementation are stage 1 and stage 2, computerisation and connectivity[14]. Younger people tend to use digital communication services, and since a good information system is highly dependent on communication, it is likely to that a change in the workforce is required to maintain the different supportive systems within the industry.

5.4 RQ1: Are there any identifiable trends concerning dynamic work instructions and operator satisfaction?

The three levels of Casat were all well received and the consensus is that every single version is an improvement over the current system when it comes to user satisfaction advantages, this applies to all operator skill levels. It can be seen from the tests that increased cognitive support leads to faster information acquisition, faster assembly times and fewer errors for novice operators. This finding is also supported by literature[8][9][10].

Some operators did, however, believe that Sprint instructions are better for expert operators. Their motivation for their opinion was that they think that the expert work by memory alone and they know how to find the critical information in Sprint. They also thought that having to verify their assembly steps continually could slow them down. This was discussed in the interviews with the operators and when it was mentioned that an operator in a future scenario would be able to selectively choose what information they want to see, and decide the amount of quality assurance (to a degree) they would receive they believed that digital instructions could work well even with an expert operator.

The term 'User satisfaction' is hard to define since operators have a different perception of satisfaction, some operators find satisfaction in performing high-quality products with as few errors as possible, some, as mentioned earlier, prefer to work in their own pace to be able to get longer, coherent pauses. What is found to be common for all operators in the collected data is that user-involvement is something that is necessary for a high user satisfaction, this is also mentioned in previous studies[5]. The implementation of dynamic digital work instructions should aim to have a close collaboration between the operators and the instruction/product designers. The operators need to be able to directly affect what comes up on their screens, including such as images and text. Problems and need to be handled quickly to ensure that a high system trust is kept.

Two other main influencing determinants to user satisfaction are task compatibility and attitude towards technology. The latter can in cases of technological resistance be overcome with training[5]. The former, task compatibility, can be a problem in the industry. The implementation of a digital instruction needs to pay respect to what the task is. Having a system in place that requires operator input and interaction without it benefiting the operator will lead to a lowered satisfaction. With the help of a dynamic system, every operator can receive the right amount of support making the instructions, even more, task compatible. A system that supports the operator and makes their work easier will have a positive effect on the satisfaction.

The possibility of having adjustable operator preferences in the form of font size, image size, and what is displayed on the screen within the current competence level will increase the user-satisfaction. When observing the operator tests, some operators preferred to zoom and view one image at the time while other preferred to keep more than one image visible during the assembly task.

The general requirement for a dynamic system includes quick updates of information. The current system, Sprint, requires a time of three weeks for updates in instructions to be available for the operators. Results show that intrinsic issues in combination with long update-times are causing poor reputation and trust in the system. Another essential requirement of the system is tool-integration, by using tool-integration as built-in quality control (scanning and confirmations from the nut runner), the operators do not have to keep track of as many vital steps. The can instead rely on the system to help them, this might reduce stress as well as errors performed in the assembly.

There appears to be a connection between the amount of cognitive support, i.e. images, text and automatic quality control, and user involvement and the operator user satisfaction.

5.5 RQ2: What are the major intrinsic and extrinsic factors affecting operators perception of dynamic work instructions?

Through the results gathered in this project, it's seen that the operators' intention to use an instructional information system is highly dependent on its content. The identified and categorized issues stated in chapter 4.3 are linked to the model seen in 2.1, the problems regarding intrinsic factors are believed to make the informational content of the instructions untrustworthy because of low believably and poor reputation of Sprint due to errors, lack of instructions, etc. Even if 'Questionable information' is categorized as an extrinsic dimension[4], it's seen that its underlying cause is within the actual informational content, which is this report is referred to as an intrinsic dimension. Another major issue that contributes to the untrustworthiness is the low rate of updates to the instructions, which may indicate a low service quality of the information system, as service quality refers to the responsiveness and support the users will receive[5].

A low service quality regarding updates and provide information to fulfill the operator need will result in poor believably and trust issues towards the instructional content. In figure 5.1 the connection between the operators' intention to use instructions and service quality is shown. Some criteria of the information system to ensure a high service quality that needs to be achieved are[5];

- Up-to-date hardware and software.
- Dependable
- Responsiveness and quick updates to users.

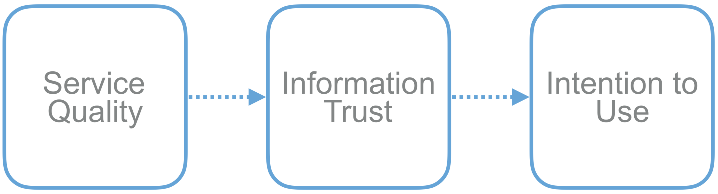


Figure 5.1: Intention to use is highly dependent on a good service quality.

Even if these are identified within the use of Sprint instructions, it's assumed that there will be the same untrustworthiness in digital, dynamic work instructions caused by intrinsic issues and absent, high service quality. The reason for this assumption is that no difference was seen between the Sprint instructions and the tested, dynamic instructions gathered data regarding intrinsic issues since these problems are related to the operators needed information. The same information will be required by the same operator regardless of how the information is presented.

In addition to the intrinsic factors that affect user satisfaction, there are extrinsic factors, and these are more complex since they're harder to measure and are dependent on the individuals' perception of information.
Through the results of the tests and analysis in this project, it's seen that most of the operators prefer images over text, and this is one of the most crucial issues with the current instructions and how the information is presented to the operators is crucial for the user satisfaction and is as mentioned, dependent on the individual.

Not only images will support the operators, but the adaptation of content to individuals. Experienced users and novice users can't use the same amount of instructional material efficiently, and the tests show that there is no "one-size-fits-all" solution to work instructions, at least without training. During the tests where novice operators used the Sprint or As Is instruction, all operators needed assistance from the test supervisors to complete the tasks, and expert operators that generally complete their daily activities and assembling by memory did not need the amount of support and instruction provided by the more detailed instructions. Instead, it slowed them down and forced them to do operations in smaller steps consuming even more time. To ensure an adaptable and flexible instructional information system operators need to be able to participate in the development and improvement of the information system. To reach high user satisfaction, the operator, depending on their background and preferences need to receive the right amount of information, no more and no less. In the framework by A.Haug, for instance, "Too large amount' and 'Too complex content' are part of the extrinsic dimensions[4], but through the analysis of the data gathered in this project, a correct way of expressing these issues would be 'Unmatched amount' or 'Unfitting complexity.'

5.6 Limitations

Initial planning for the operator tests at the Tuve Plant involved 24 operators which correspond to three different skill levels and four different informational levels, all with two replications. However, during the test weeks in the plant, the various departments and lines in the factory had some issues regarding sick-leave, improvement work, holidays and disturbances that resulted in a lack of operators for the tests.

When the tests ended, 14 operators had participated in the tests which was considered enough of a sample size to find indications of trends, however for a future test it would be recommended to have several more tests.

The operators were also meant to test two different variants of the product they were assembling, but due to lack of time during the tests, only one variant was tested which resulted in fewer data.

Casat, the software used to create test instructions for the operator tests does not support all features that previously have been requested in the initial planning of the GAIS2 project which of this project is a part.
Examples of these features are:

- Information levels
- Competence categorization
- Dynamic information control

These features were instead handled manually by creating several independent versions.
The three different information levels were created without any previous input from operators at the assembly. Improvements suggested by the operators were not implemented between the different tests to ensure that all operators experience the same tests.
The work instructions were created in a logical and iterative process and repeatedly tested by the creators before the actual operator tests. Future studies on the subject should cooperate with operators to create the instructions as it is the operators themselves that hold the knowledge of what they need.

5.7 Validation of test integrity

Since the sample size of these test was so small and the operators of a narrow group some questions regarding the test validity are up for discussion.

Creswell [21] brings up several threats to the validity of mixed method research design, in the quantitative part the most significant threats that this experiment has encountered are;

- Creswell recommends using multiple approaches to improve the accuracy of the finding, this was done through triangulation. Triangulation is used to build a trend from data from several different sources, in this case, both qualitative and quantitative data. This increases the validity of the study [21].
- Participant has the same characteristics in the form of technological attitude. This means that the implementation may yield other results with a more resistant group.
- Participants come from two different work areas in the factory. The implementation of digital instructions may meet more resistance in places where it is harder to implement.

Due to the limitations of the testing, these two areas cannot be validated without more tests. The rest of the threats, both internal and external are considered for and are not an issue in the reliability of the data.

Throughout this thesis, the authors have attempted to be as consequent, transparent and consistent as possible to ensure that the test environment and conditions have been equal in between the operators. This is to achieve reliability, a new set of operators should generate the same results[26]. However as mentioned earlier, this may be problematic as these tests had a group of technologically optimistic operators from a small part of the factory.

5.8 Industrial implications

As the market demands are ever-changing, so must the industry. The customer of today expect more personalization and customization, therefore the industry must as well. And as the industry pushes more and more variants through, not only the mechanical and robotics must adapt, but also the humans. Some jobs may disappear and may be replaced by new ones, however, the manual assembly jobs will be around for a while longer and the industry must support the people working there. One key aspect is that of cognitive support. As mentioned in the theory chapter on cognitive support, much research shows that to increase the cognitive support for the operator, changes need to be made in the work instructions[11][12][13]. More adaptable depending on skill level[8], information easier to acquire[10]

Industry 4.0 is the current buzzword in the industry and from the finding of this project, it is believed that dynamic digital instructions are a necessity to allow the people that work in manual assembly to keep an even pace with all the other changes. At the same time as 4.0 systems are implemented, digital work instructions need to be implemented as well as integrated with the other systems. After proper implementation, the preparation for new variants should be easier due to the variant driven nature of digital instructions such as Casat. Once one variant is implemented, the only changes that have to be made are for the differences which then can be reused in combination with other differences to create a new product. Without writing or modifying a single instruction.

Another positive outcome is the sustainability. Printing several thousand papers, regardless if they are used or not is a strain both on the environment as well as the economy of the company. Replacing this with a digital is a gain in both dimensions. As for the social sustainability the most important aspect would be the trust the users will have in the system, especially since they are able to affect it more. Trust in the information and the system is critical for social sustainability.

The studies conducted in this project strengthens the theories and framework created by Haug[4], multiple examples of intrinsic and extrinsic issues related to the informational content of work instructions were found during the tests, observations, and interviews. These different issues can also be linked to the operators' perception and confidence in their work instructions. Different instructional information levels containing different layouts and visual supports were also found to affect the operators and the 'Design principles For Information Presentation' suggested by Mattsson[11] were strengthened by the results shown in this project.

5.9 Future work

Due to the number of limitations experienced it is recommended that further tests and studies are conducted in regards to user adapted instructions dynamic insturcions. What is needed is more operators, more variants and preferably testing on other assemblies than the bogie. For example, it is believed that testing it on a driven line would yield other results as they have other requirements than that of the preassembly. It would also be interesting to allow an operator to test several of the different instructions to see what is preferred by the individual.

Another important point is that closer work with the operators that actually use the system is needed during the development. They know best how they want their information presented and what information they do need. In a real factory scenario, the instructions would be developed by the operators together with the engineers to ensure that the information follows the current best standard and that the information presented is relevant and sufficient as well as being presented in an efficient and cognitive way. The cognitive support is critical in variant-driven industry. The operators should also be allowed to either test actual dynamic instructions or being able to test several of the static ones. There were four different sets of instructions in this experiment. However, the operators only tried one each. Furthermore, additional connected tools and built-in quality control could be tested to evaluate performance and quality depending on operator skill.

6

Conclusion

Relations between the dynamic work instructions and the operators' satisfaction were found. An operator that received timely, correct and efficient instructions and information has a higher satisfaction. It could also be seen from the interviews that operators wanted to interact and control their own work instructions more. A control which can be enabled by the implementation of digital dynamic instructions and therefore increase the user satisfaction of the operators. The operators want to contribute to a better workplace and their input has to be embraced, especially since the operators hold critical knowledge of the assembly process.

Different factors are affecting the operators' perception of their work instructions, findings in this project show that one of the most significant issues with instructional information in general is poor updates and poor believability of the information. Information needs to be updated for the operators to trust their given instructions, otherwise, it will not be used which leads to quality problems in the production. Apart from up-to-date instructions, representational issues are also important to address, the informational content needs to be adapted to the different operators based on their skill and personal preferences. There is no "one-size-fits-all" solution to work instructions.

A system of dynamic digital instructions with the potential of high individual customization will enable the operators to work at their best by receiving just the right amount of support in their work so it does not hinder an expert nor contains too little information to guide a novice. The tests have shown improvements in quality from better instructions with software integrated quality control. The operators also thought that the demonstrator was a close representation of the real system that it was suitable for the experiments.

The findings from the results are that operators of today are supportive to technology, much due to their own daily use in their private lives and are positive to the implementation of technological aids in their workplace. The positive attitude towards technology means that some of the most crucial determinants of a system success are already in place. The problem lies within industry and organizations to embrace it and start moving forward past the current frontier and moving in to new ground. Industry must keep up with the shift that is happening driven by Industry 4.0 on all fronts, including that of work instructions.

Bibliography

[1] Johansson, P. E., Enofe, M. O., Schwarzkopf, M., Malmsköld, L., Fast-Berglund, Å, Moestam, L. (2017). Data and Information Handling in Assembly Information Systems – A Current State Analysis. Procedia Manufacturing, 11, 2099-2106

[2] Johansson, P. E., Delin, F., Jansson, S., Moestam, L., Fast-Berglund, Å. (2016). Global Truck Production – The Importance of Having a Robust Manufacturing Preparation Process. Procedia CIRP, 57, 631-636.

[3] Chalmers University of Technology. 2018. Global Assembly Instruction Strategies (GAIS) 2. [ONLINE] Available at: https://www.chalmers.se/en/projects/Pages/Global-Assembly-Instruction-Strategies-QGAISQ-2.aspx. [Accessed 7 February 2018].

[4] Haug, A. (2015). Work instruction quality in industrial management. International Journal of Industrial Ergonomics, 50, 170-177.

[5] Petter, S., Delone, W., Mclean, E. R. (2013). Information Systems Success: The Quest for the Independent Variables. Journal of Management Information Systems, 29(4), 7-62.

[6] The DeLone and McLean Model of Information Systems Success: A Ten-Year Update. (2003). Journal of Management Information Systems, 19(4), 9-30.

[7] Delone, W. H., Mclean, E. R. (1992). Information Systems Success: The Quest for the Dependent Variable. Information Systems Research, 3(1), 60-95.

[8] Sheridan, T. B. (2002) Human and Automation: System Design and Research Issues. Santa Monica, CA: John Wiley Sons, Inc.

[9] Mattsson, S., Fast-Berglund, Å. (2016). How to Support Intuition in Complex Assembly? Procedia CIRP, 50, 624-628.

[10] Bäckstrand, G., Thorvald, P., De Vin, L., Högberg, D. Case, K. (2008) The impact of information presentation on work environment and product quality: a case study. Proceedings of the 40th annual Nordic Ergonomic Society Conference. Reykjavik, Iceland.

[11] Mattsson, S. (2018). Towards increasing operator wellbeing and performance in complex assembly, Chalmers University of Technology, Gothenburg.

[12] Fast-Berglund, Å. Blom, E. (2014). Evaluating ICT-Tools for Knowledge Sharing and Assembly Support. In Applied Human Factors and Ergonomics AHFE 2014; 19-23 July 2014, Kraków, Poland.

[13] Holm, M., Adamson, G., Wang, L. Moore, P. (2014). THE FUTURE SWEDISH SHOPFLOOR OPERATOR.

[14] Schuh, G., Anderl, R., Gausemeier J., ten Hompel, M., Wahlster, W. 2017. Industrie 4.0 Maturity Index. Managing the Digital Transfor-

mation of Companies (acatech STUDY), Munich: Herbert Utz Verlag. http://www.acatech.de/publikationen

[15] Pinzone, M., Fantini, P., Perini, S., Garavaglia, S., Taisch, M., Miragliotta, G. (2017). Jobs and Skills in Industry 4.0: An Exploratory Research. Advances in Production Management Systems. The Path to Intelligent, Collaborative and Sustainable Manufacturing IFIP Advances in Information and Communication Technology, 282-288.

[16] Kekolahti, P., Karikoski, J., Riikonen, A. (2014). The effect of an individual's age on the perceived importance and usage intensity of communications services—A Bayesian Network analysis. Information Systems Frontiers, 17(6), 1313-1333.

[17] Bogue, R. (2012). Design for manufacture and assembly: Background, capabilities and applications. Assembly Automation, 32(2), 112-118.

[18] Boothroyd, G., Dewhurst, P., Knight, W.A. Taylor Francis (2002;2001). Product design for manufacture and assembly, 2nd, rev. and expand edn, M. Dekker, New York.

[19] Creswell, J.W, 2014. Research design: Qualitative, Quantitative and Mixed Methods Approaches. 4th ed. United States of America: Sage Publications Ltd.

[20] Juliet Corbin (2017). Grounded theory, The Journal of Positive Psychology, 12:3, 301-302.

[21] Creswell, J.W., Plano Clark, V.L, 2011. Designing and Conducting Mixed Methods Research. 2nd ed. United States of America: Sage Publications Ltd.

[22] Nebim.eu 2018. Volvo Deutch Reseller. [ONLINE] Available at: https://nebim.eu/volvo-trucks/volvo-fmx. [Accessed 5 June 2018].

[23] ABryman, A., Bell, E. (2003). Business Research methods. Oxford: Oxford University Press.

[24] Johansson, P., Eriksson, G., Johansson, P. et al 2017 Assessment Based Information Needs in Manual Assembly DEStech Transactions on Engineering and Technology Research ICPR 2017: 366-366

[25] Friedman, Hershey Amoo, Taiwo. 1999. Rating the Rating Scales. Journal of Marketing Management. 9. 114-123.

[26] Flynn, B. (1990). Empirical research methods in operations management. Journal of Operations Management, 9(2), 250-284.

A
Appendix 1

A.1 General requirements GAIS

FR	Name	Feature
1	Login	All workers shall be logged in to the AIS with a User ID for best user experience.
2	Profile	All users shall have a profile containing Name; User ID; Language preference; Competence levels; Certifications; viewer preferences; Operator height; Text size
3	Competence categorization	All users shall be categorized on basis of knowledge, experience, certifications/training, and specific job time spent which is handled in a competence centre FR4.
4	Competence Centre	A Competence Center shall be implemented connecting competence level FR5 to profile FR2 for manual adjustment of an admin.
5	Competence levels	3 competence levels should be implemented; Learning, Normal, Skilled and are connected to different information levels FR7.
6	Standard language	Standard language shall be set to English (US). Display language shall be set to Swedish.
7	Information LVL	Information is presented according to 3 different competence levels FR5. Information level 1 contains WHAT Information level 2 contains WHAT, HOW, WHERE, (WHY) Information level 3 contains WHAT, HOW, WHERE & WHY.
8	Dynamic information control	The information contents on the screen depend on active competence level for logged in user and viewer preferences ID12.
9	Optional – API	A device neutral API shall be implemented to support different external tools using standard connectivity interfaces such as NFC, BTH, AirPlay, WNET, WI-FI, USB or equivalent
10	Optional – Mobility	Demonstrator must enhance information mobility allowing different wearables for presenting information and control of the Digital Instruction Engine.
11	Media support	Demonstrator needs to be able to handle media as; text documents (pdfs?); images; movies (optional)
12	Viewer preferences	All user should be able adjust what and how is displayed on the screen within current competence level. Main information should be adjusted to fit the height of the operator FR2. (To be evaluated by operators through mock ups).
13	Back compatible viewer preferences	The experience operator should be able to during an operation access more detailed information if needed. (e.g. activate Normal and Learning) FR5
14	Training material connected to operations	All training material should be connected to real assembly information. This means that the most detailed assembly information is presented in Learning level FR5.
15	Feedback report	When user is logged in, operator should be able to access a feedback report in the menu.
16	Feedback in real-time	User should be able to get real-time feedback displayed on current product if deviations have previously been made and documented.
17	Passive feedback	Operator should be provided with feedback directly on screen only if no work is to be carried out on the assembly station for the moment.
18	Feedback loop	It should be able to provide feedback on: • quality defects discovered from previously assembly stations • quality defects from current work • concerns relating to current procedure
19	Assembly work instruction content	Assembly work instructions shall contain: • Part name

		• Part numbers • Part quantity • Position • Procedural description • Reason why And should be in the text, picture and movie format according to FR11.
20	Assembly work instruction	An assembly work instruction shall present assembly work tasks in logical order.
21	Tool integration	Assembly task performed with a connected tool should automatically control the assembly task approval process in the system and show relevant feedback to user.
22	Optional – Andon	The system should support integrated Andon functionality
23	Optional – gamification	To support testing of satisfaction in gamification functionality: Automatic changes and approval of new competence levels, both promotion and degradation, based on quality feedback.

A.2 Questionnaire responses

Variant:

13 av 13 människor besvarade denna fråga

1	SINGLE	13 / **100%**
2	DOUBLE	0 / **0%**

Layout:

13 av 13 människor besvarade denna fråga

1	OPTIMAL EXPERT	4 / **31%**
2	OPTIMAL NOVICE	4 / **31%**
3	AS IS	3 / **23%**
4	BASIC	2 / **15%**

Tidigare erfarenthet:

13 av 13 människor besvarade denna fråga

1	Aldrig monterat bogiebalk	5 / **38%**
2	Arbetar regelbundet med bogiebalk	5 / **38%**
3	Arbetar vid enstaka tillfällen med bogiebalk	3 / **23%**

Jag använder regelbundet dator/smartphone/surfplatta:

13 av 13 människor besvarade denna fråga

1	Ja	13 / **100%**

Jag använder regelbundet följande digitala tjänster:

13 av 13 människor besvarade denna fråga

1	Internet	13 / **100%**
2	SMS	13 / **100%**
3	Musik	12 / **92%**

4	Samtal	11 / **85%**
5	Navigation	7 / **54%**

Jag får helst mina nyheter via:

13 av 13 människor besvarade denna fråga

1	Telefon/Surfplatta	12 / **92%**
2	TV	7 / **54%**
3	Radio	5 / **38%**
4	Tidning	5 / **38%**

Jag upplever användarvänligheten med ny vardaglig teknik som:

13 av 13 människor besvarade denna fråga

1	Enkel	12 / **92%**
2	Varken eller	1 / **8%**
3	Svår	0 / **0%**

Om jag får problem med min dator/telefon tar jag i första hand följande åtgärd:

13 av 13 människor besvarade denna fråga

1	Söker information för att lösa problemet	7 / **54%**
2	Löser problemet självständigt	4 / **31%**
3	Tar hjälp av annan person	2 / **15%**

Jag känner mig trygg med att använda ny teknik som jag ej använt förut:

13 av 13 människor besvarade denna fråga

1	Instämmer helt	7 / **54%**
2	Instämmer delvis	6 / **46%**
3	Instämmer ej	0 / **0%**

Jag använder SPRINT i mitt dagliga arbete:

13 av 13 människor besvarade denna fråga

1	Instämmer helt	5 / **38%**
2	Instämmer delvis	4 / **31%**
3	Instämmer ej	4 / **31%**

Jag tycker att SPRINT effektivt stödjer mitt arbete:

13 av 13 människor besvarade denna fråga

Medel: 3.15

1	2	3	4	5
Instämmer ej		Instämmer delvis		Instämmer helt

3	4 / **31%**
2	3 / **23%**
4	3 / **23%**
5	2 / **15%**
1	1 / **8%**

Jag tycker att SPRINT ger mig den information jag behöver:

13 av 13 människor besvarade denna fråga

Medel: 3.23

1	2	3	4	5
Instämmer ej		Instämmer delvis		Instämmer helt

3	4 / **31%**
2	3 / **23%**
5	3 / **23%**
4	2 / **15%**
1	1 / **8%**

Jag upplever att SPRINT innehåller korrekt information:

13 av 13 människor besvarade denna fråga

Medel: 2.46

1	2	3	4	5

Instämmer ej | Instämmer delvis | Instämmer helt

1	4 / **31%**
3	4 / **31%**
4	3 / **23%**
2	2 / **15%**

Jag upplever att SPRINT innehåller onödig information:

13 av 13 människor besvarade denna fråga

Medel: 3.46

1	2	3	4	5

Instämmer ej | Instämmer delvis | Instämmer helt

5	5 / **38%**
1	3 / **23%**
4	3 / **23%**
2	1 / **8%**
3	1 / **8%**

Jag anser att fel i SPRINT åtgärdas snabbt:

11 av 13 människor besvarade denna fråga

Medel: 2.09

1	2	3	4	5

Instämmer ej | Instämmer delvis | Instämmer helt

1	5 / **45%**
2	2 / **18%**
3	2 / **18%**
4	2 / **18%**

Jag upplever att jag i dagsläget kan påverka innehållet i SPRINT:

11 av 13 människor besvarade denna fråga

Medel: 3.09

1	2	3	4	5

Instämmer ej | Instämmer delvis | Instämmer helt

3	3 / **27%**
5	3 / **27%**
1	2 / **18%**
2	2 / **18%**
4	1 / **9%**

Jag upplever att jag hade använt SPRINT mer om instruktionerna motsvarade mina förväntningar kring korrekt, onödig och korrigerad information:

11 av 13 människor besvarade denna fråga

Medel: 4.00

1	2	3	4	5

Instämmer ej | Instämmer delvis | Instämmer helt

5	5 / **45%**
4	3 / **27%**
3	2 / **18%**
1	1 / **9%**

Jag upplevde mängden bilder i instruktionerna som:

9 av 13 människor besvarade denna fråga

Medel: 3.00

1	2	3	4	5

För få | Lagom | För många

3	5 / **56%**
1	1 / **11%**
2	1 / **11%**
4	1 / **11%**
5	1 / **11%**

Jag upplevde bildkvalitén som:

9 av 13 människor besvarade denna fråga

Medel: 4.11

1	2	3	4	5

Dålig | Helt ok | Bra

5	4 / **44%**
3	3 / **33%**
4	2 / **22%**

Jag anser att bilderna fokuserade på rätt delar och områden:

9 av 13 människor besvarade denna fråga

Medel: 4.00

1	2	3	4	5

Instämmer ej | Instämmer delvis | Instämmer helt

5	4 / **44%**
3	2 / **22%**
4	2 / **22%**
2	1 / **11%**

Jag upplevde mängden text i instruktionerna som:

11 av 13 människor besvarade denna fråga

Medel: 3.09

1	2	3	4	5

För lite | Lagom | För mycket

3	10 / **91%**
4	1 / **9%**

Jag upplevde formuleringarna i texterna som:

11 av 13 människor besvarade denna fråga

Medel: 3.55

1	2	3	4	5

Svåra att tolka | Varken eller | Enkla att tolka

3	5 / **45%**
4	3 / **27%**
5	2 / **18%**
2	1 / **9%**

Jag upplevde menyer och navigering i systemet som:

11 av 13 människor besvarade denna fråga

Medel: 3.36

1	2	3	4	5

Svår	Varken eller	Enkel

3	5 / **45%**
2	2 / **18%**
4	2 / **18%**
5	2 / **18%**

Navigeringen i menyerna fungerade som jag förväntade mig:

11 av 13 människor besvarade denna fråga

Medel: 4.00

1	2	3	4	5

Instämmer ej	Instämmer delvis	Instämmer helt

4	7 / **64%**
3	2 / **18%**
5	2 / **18%**

Jag *tycker* att följande instruktionstyp har högre användarvänlighet:

11 av 13 människor besvarade denna fråga

1	Digitala instruktioner	10 / **91%**
2	SPRINT	1 / **9%**
3	Jag anser att alternativen är likvärdiga	0 / **0%**

Jag *tror* att följande instruktionstyp är mer lämplig att använda för en erfaren operatör:

11 av 13 människor besvarade denna fråga

1	Digitala instruktioner	6 / **55%**
2	SPRINT	4 / **36%**
3	Jag anser att alternativen är likvärdiga	1 / **9%**

Jag *tror* att följande instruktionstyp skulle minska mängden misstag jag gör:

11 av 13 människor besvarade denna fråga

1	Digitala instruktioner	10 / **91%**
2	SPRINT	1 / **9%**
3	Jag anser att alternativen är likvärdiga	0 / **0%**

Jag *tror* att följande instruktionstyp är lättare att använda för en nybörjare:

11 av 13 människor besvarade denna fråga

1	Digitala instruktioner	9 / **82%**
2	Jag anser att alternativen är likvärdiga	1 / **9%**
3	SPRINT	1 / **9%**

Jag vill kunna påverka innehållet i mina arbetsinstruktioner:

13 av 13 människor besvarade denna fråga

1	Ja	13 / **100%**