MÄLARDALEN UNIVERSITY
SWEDEN

School of Innovation, Design and Engineering

VOLVO
CONSTRUCTION EQUIPMENT

Exploring challenges in a verification process – when adapting to new environmental requirements

Thesis work

Bachelor level,15 credits

Product- and process development
Industrial design

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Report number:…
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ABSTRACT
The requirements on the products and production processes within the manufacturing industry are continuously increasing according to environmental standards. The new requirements are coming from a growing awareness of what our planet can provide for example by the global challenge of climate change. The industry needs to reduce energy consumption and waste to meet the upcoming requirements.
One of the processes with high environmental impact in a discrete manufacturing industry is the paint shop. Surface treatment is also of great importance to maintain a high quality product. In scientific literature, technological risk is one of the barriers in implementing environmental conscious manufacturing. Therefore the area of sustainable operations management needs building bridges with other functions and disciplines such as economics, strategies and behavioral sciences in order to manage the transitions. The supply of competence around paint shops today is usually provided by suppliers and other sources within the industry and to make the collaboration to work is essential. In this process of collaboration with external sources, substantial measurements are required to maintain the desirable quality. In order to ensure the competence of testing the quality eventuate when switching technology at a pre-treatment line, this report sets out to explore what the challenges to be taken into consideration are when to assure the product- and- process quality. To respond to this question, a multiple case study is conducted during spring 2016 where the phenomenon to study is the change process and the unit of analysis is the challenges that can be faced during the verification process. The case studied is automotive companies located in Sweden which are producing components for heavy duty vehicles. Data collection is performed by studying documents, participatory observations and semi-structured interviews. The results will give insights to academia on what challenges that are occurring during the verification process of implementing new and cleaner technologies. The conclusions are drawn upon the literature and the empirical results. The managerial implications are to increase the awareness of any potential barriers in the verification process in order to be prepared for managing the technological change process.

SAMMANFATTNING

Kraven på produkter och produktionsprocesser inom industrin ökar tack vare högre miljöstandarder. De nya kraven kommer från en växande medvetenhet om vad vår planet kan klara av, till exempel den globala klimatutmaningen. Industrin behöver minska energiförbrukningen och mängden avfall för att kunna möta de uppkommande kraven.
En av processerna med hög miljöpåverkan i en diskret tillverkningsindustri är måleriet. Ytbehandling är också av stor betydelse för att upprätthålla en produkt av hög kvalitet. I den vetenskapliga litteraturen, är teknisk risk ett av hindren i införandet av miljömedveten tillverkning. Området hållbar verksamhetsstyrning behöver därför bygga broar med andra funktioner och discipliner såsom ekonomi och beteendevetenskap för att hantera övergångarna. Kompetensförsörjning runt målerier idag tillhandahålls vanligtvis av leverantörer och andra källor inom industrin och samarbetet här är avgörande. I den här samarbetsprocessen med externa källor, behövs rejäla åtgärder för att bibehålla den önskvärda kvaliteten. För att säkerställa kompetensförsörjningen kring verifiering av kvalitetsutfallet när ny teknik införs i en förbehandlingslina, avser denna rapport att utforska vilka utmaningar som finns att ta hänsyn till vid säkerställande av produkt-och processkvaliteten. För att kunna svara på forskningsfrågan utförs en multipel fallstudie under våren 2016 där fenomenet som ska studeras är förändringsprocessen och analysenheten är utmaningarna som kan uppstå under verifieringsprocessen. Fallstudien består av fordonstillverkare i Sverige som tillverkar komponenter till tyngre fordon. Datainsamlingen utförs genom att en litteraturstudie, deltagande observationer och semi-strukturerade intervjuer. Resultaten kommer ge insikter till akademien om vilka utmaningar som uppstår i verifieringsprocessen vid implementeringen av ny och renare tekniker. Slutsatserna dras baserat på litteraturstudien och de empiriska resultaten. Innebörden för praktiska tillämpningar handlar främst om att öka medvetenheten kring utmaningar i verifieringsprocessen, för att kunna vara förberedd och hantera den tekniska förändringsprocessen.

PREFACE

My interest in technology have been life long, but was increased in level even more when I got the opportunity to be a junior trainee at a material technology laboratory at Volvo Construction Equipment (VCE) in Eskilstuna, Sweden directly after “high school”. Less than a year later I began my university studies at Malardalen’s University (MDH) to become a mechanical engineer within innovation and product design. During two summers I got the opportunity to work at the same material technology laboratory. This is where I met Pia Nuija (Supplier Development Engineer, Paint & Surface Treatment now), who saw the need for this type of thesis work and connected me to Anna Sannö (Ph.D. student at INNOFACTURE, MDH), who became one of my mentors during this project. I want to direct a huge thanks to Pia Nuija and Anna Sannö!

I got the opportunity of having two mentors at the company; I would also like to thank Rolf Allansson (production engineering) for all the assistance in practical matters on site in Hallsberg, Sweden! The process operators on site have contributed with knowledge of the production process, which have given me a greater insight in their daily work, thank you for your time and commitment! The supplier of chemicals has been a great support in formulating a test plan to the actual project on site, thank you for your help! I would also like to thank all the respondents for their time and commitment to answering all the questions! Finally, I would like to thank Ragnar Tengstrand, my mentor at MDH!

Contents

1. INTRODUCTION

1.1. Background

The requirements on the products within the manufacturing industry are continuously increasing according to environmental standards, coming from legislation, society and limited resources of the earth (UNEP, 2015, European Environment Agency, 2010, European Chemicals Agency, 2014, European IPPC Bureau, 2010). The industry for example needs to reduce energy consumption and waste to meet the requirements from new legislation. One of the environmental incriminating processes in the production is the paint shop (EU, 2006). Paint and surface treatment is also of great importance to maintain a high quality product (Geffen and Rothenberg, 2000). Companies using this production process need to proceed with substantial measurements when changing it, in order to maintain the desirable standard. Barriers have been identified when adopting the technology to environmentally conscious manufacturing (Mittal and Sangwan, 2014, Luken and Van Rompaey, 2008, Sannö et al., 2015) as well as implementation of environmental strategies (Bey et al., 2013, Murillo-Luna et al., 2011) and practices (Höckerdal, 2012). Technological risk is seen as one of the barriers when implementing environmentally conscious technology adoption (Mittal and Sangwan, 2014, Sannö et al., 2013) which is related to finding information about alternative technologies in the production (Luken and Van Rompaey, 2008, Bey et al., 2013). It is however less explored in the operation management literature how this process can be managed and the challenges that arise when adopting a new environmental conscious technology while maintaining the same product- and process quality standard.
In order to be able to conduct the technology switch, or a process innovation, it is not only the technological change that is important but also organizational change (Ettlie et al., 1984, Rogers, 2003). According to Frishammar et al. (2011) it is not enough to manage uncertainty in product-and process innovation, but also important to manage vagueness especially in the early phases of the project. It is also common that the supply of competence when changing a paint line is usually provided by the chemical suppliers and also comes from other sources within the industry (Geffen and Rothenberg, 2000).
In order to better understand the process of innovation related to managing environmental technological change in production, a multiple case study is performed. Taking the operational change into consideration this study explores the verification process while testing the quality eventuates when switching technology at a pre-treatment process.

First the theoretical framework describes existing literature on sustainable production to be followed by challenges found in the literature faced when managing environmental projects. The literature on process innovation is thereafter used to understand the area of technology adoption. After that the research approach is described and the next section is presenting the empirical findings from the case study. Finally the article presents a discussion as well as conclusion with implications for practice.

1.2. Problem formulation

The manufacturing industry is under pressure to reduce the environmental impact, but still maintaining the product and process quality, preferably with an economic supportable solution. This sets high requirements on the organizations, encountering challenges on the way of implementing environmentally less incriminating production processes; this study sets out to explore these challenges.

1.3. Purpose and research questions

To theoretically and practically ensure the competence of testing the quality eventuates when switching technology at pre-treatment.

R.Q1: What challenges needs to be taken in to consideration to maintain the product- and-process quality when verifying production processes adapted to new environmental requirements?

R.Q2: How can a statement of intent look like to assure the quality when switching the technology at a paint shop?

1.4. Directives

Volvo Construction Equipment (VCE) needs two statements of intents on how to change and implement an innovative pre-treatment line in two major steps, which is the contribution for practice.
The data collection will contribute to the research study at INNOFACTURE and VCE mainly conducted by Anna Sannö. This will also result in a conference article, which will be submitted and hopefully accepted for publishing and presentation at the Swedish Production symposium 2016 (SPS'16). The conference article will hopefully contribute with insights to academia regarding process innovation and sustainable production with focus on what challenges can occur when adapting production processes to environmental requirements.

1.5. Limitations

The thesis work comprises of 15 hp. within mechanical engineering with the main area of product- and- process development- industrial design at a level called G2E. The degree project is executed on half time, corresponding to about 20 hours per week during one semester.

This study has however some limitations. In this study we have focused on chemical based production processes in a discrete manufacturing setting, which is a limitation of the study. However, this is a common process also in the discrete manufacturing context. This is also considered when adding a spackling paste company to the study. In order to increase the validity, observations have complemented the interviews as well as a final work shop to discuss the results and triangulate the data. The reliability can also be discussed since we have selected the respondents based on coauthors earlier experience. The literature search could have been extended also to further literature in process innovation and manufacturing technology literature, which is seen as a future direction for research.

2. RESEARCH METHOD

The main focus of the study is on challenges in the verification, as the process of confirming or checking the accuracy in terms of quality of the new technology. The challenges are studied when developing innovative processes, primarily in pre-treatment facilities. The research strategy is a multiple case study of companies in Sweden producing heavy duty vehicles within the construction equipment segment but similar technology switch has also been evaluated by trucks, buses and engines manufacturing organizations. The participating observations are conducted during a four month period with focus on the paint shop at one manufacturer of construction equipment. See figure 1 for the research method.

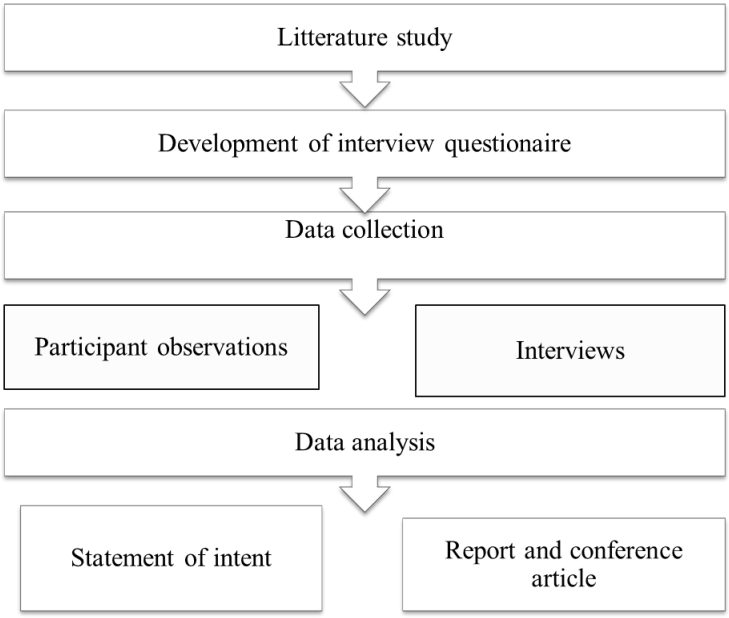

Figure 1: Research method.

First of all, a literature study is conducted, in order to find relevant literature of challenges, barriers in the sustainable operations management literature as well as to seek advice from process innovation to build a theoretical framework.
The empirical study consists of two parts; a series of semi-structured interviews as well as participating observations in the actual production setting. Except the participating observations, some documentation on site where studied.
In the selected cases, there is an interest in adopting new and innovative manufacturing processes, driven by a willingness to work proactive rather than reactive concerning environmentally less incriminating processes. There are ongoing projects in the respective organizations aiming to investigate the possibilities to adopt innovative processes.
There are different types of pre-treatments and paint systems, in a varying range of combinations, which is adjusted after the manufactured products and the requirements on the product. Some of the aspects affecting the quality of the final products are:

- Incoming material (type of material, roughness, cleanness)
- Pre-treatment (mechanical or chemical)
- ED-primer
- Top coat

Not only the type of material and products used creates the variation but also the process conditions when applied, such as

- Times
- Temperatures
- Moisture in the air
- Application method
- Thickness or weight of coating/ film

Twenty-one semi-structured interviews, varying in duration from 30 to 90 minutes, with different experts, researchers and practitioners have been conducted, see table 2. The respondents represented one manufacturer of heavy duty vehicles within the construction equipment segment (two separate plants), one manufacturer of trucks (two plants), one manufacturer of trucks, buses and engines, one chemical supplier and a manufacturer of spackling paste. The manufacturer of spackling paste was included in the interview series to cover the differences when moving in the outlines of the research fields.
The interviews were conducted during a two month period with representatives from different levels within the organizations (process operators, production technician, supplier developer, quality assurance), but also with researchers from two other big companies within the industry, the supplier of pretreatment and experts from a materials technology center. The respondents were chosen to accomplish a spread in the data collection regarding a variety of functions and roles. The interview protocol included questions about working procedure, verification of products and processes, test methods and standardization.
The interviews were recorded and transcribed by the author. The material was then coded and constructs were done (Miles et al., 2013) and the constructs were later discussed in an iterative process. Based on the literature the identified challenges were categorized as related to uncertainty or vagueness. The data were also validated by receiving feedback from the respondents as well as discussed during a workshop session, with different functions represented.

Compilation of interviews	**Number Of respondents**	**Rolls/ Title**
21 interviews	-	-
30-90 minutes/ interview	-	-
Manufacturer of construction equipment (2 plants)	9	4 Process operators 1 Production technician 1 Quality manager 2 Material technology specialists 1 global standardization leader
Manufacturer of trucks (2 plants)	4	2 researchers 1 chemical engineer 1 materials engineer, heat treatment
Manufacturer of trucks, buses and engines	3	1 head of MT 2 development engineers
Supplier of chemicals	3	1 Sales & service engineer 1 business manager automotive 1 New business developer
Manufacturer of spackling paste	2	2 product developers

Table 2: Data collection

The interviews and the participant observations constituted the data collection, which were triangulated, to empower the result. When triangulating the data, the case study has the advantage of the possibility to use more than one data source, which should increase the credibility of the results (Yin, 2009).

3. THEORETICAL FRAMEWORK

3.1. Sustainable production

Sustainable production has received an increased attention the latest decades (Kleindorfer et al., 2005) and with the demands to secure future generation's needs - environmental, economic and social (World Commission on Environment and Development, 1987), it is clear that manufacturing industry and their supply chain needs to in greater extent consider the transition to sustainable production in many aspects for example decision-making while implementing new technologies in the supply chain (Walker et al., 2014, Carrillo et al., 2015) as well as diffusion of innovations in the supply chain (Sarkis et al., 2011). However, Mittal and Sangwan (2014) by many (Bey et al., 2013, Luken and Van Rompaey, 2008), has explored and related barriers for successfully implementing environmental conscious manufacturing. Some of these are; low enforcement, uncertain future legislation, high short term costs, uncertain benefits, low customer demand, trade-offs, low top management commitment, lack of organizational resources, technological risk and lack of awareness/ information. Related to the later barriers, high environmental performance usually requires high involvement of suppliers and a relationship built on trust between the paint shop and the supplier. The plant needs the expertise of the supplier when the knowledge is absent within the paint shop (Geffen and Rothenberg, 2000). Knowledge in this paper (according to Merriam Webster dictionary) is seen as the fact or condition of knowing something with familiarity gained through experience or association. Creation of knowledge can be related to the very flow of information, anchored in the commitment and beliefs of its holder (Nonaka, 1994).

3.2. Process innovation

Process innovations can be developed in varying manners, often due to the origin of the innovation (Frishammar et al., 2011). They define process innovation as the systemic approach to developing innovative production processes. Organizing the process development in the R&D-function or in the manufacturing-function internally sets the foundation for different approaches to testing and implementing process innovations (Lager and Frishammar, 2012). That implies, if the process development is set to an external organization, the approach may be yet another.

Social constructions in societies are more important than the technology itself, when trying to implement innovations (Rogers, 2003). Values, communication, culture and traditions can be more important than logical or scientific "evidence" when trying to convince people to adopt the innovation. Interpersonal networks are important when adopting or rejecting an innovation. Diffusion is the process in which an innovation is communicated through certain channels over time among the members of a social system (Rogers, 2003).

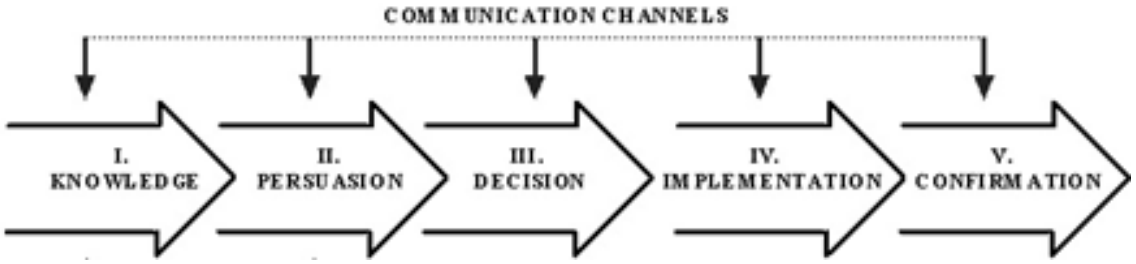

Fig. 3: A model for innovation-decision process inspired by Rogers (2003).

Figure 3, shows the model for innovation-decision process developed by Rogers (2003), consists of five stages; knowledge, persuasion, decision, implementation and confirmation. In the knowledge stage the organization finds an opportunity, which could be a potential solution to a problem, or improve a situation. In this stage, the organization gains understanding of how the innovation works, and an initial felling if the innovation's suitable as a solution. In the persuasion stage the organization begins to form an attitude, or opinion about the innovation, either positive or negative. Moving from the persuasion stage in to the decision stage includes activities to enable a decision either to adopt the innovation, or to reject it. When the organization installs, or begins to use the innovation, the process has moved on to the implementation stage. After implementation, the organization needs to confirm the decision about using the innovation and making sure the innovation is working as it's supposed to, which is in the confirmation stage.

Uncertainty is: "defined to be the lack of information needed to obtain and implement the technology to be integrated" (Stock and Tatikonda, 2008). More precisely, technology uncertainty is the difference between: the information needed by the recipient organization to obtain and implement the technology, and the information the recipient actually has at the start (Stock and Tatikonda, 2008). More innovative development efforts involve higher degrees of uncertainty, which in turn create higher risks of quality failures and associated costs (Mackelprang et al., 2015).

The process innovation implies a degree of uncertainty, but according to Frishammar et al. (2011) it is not enough to manage uncertainty in product-and process innovation, but also important to manage vagueness, especially in the early phases of the project. Vagueness, according to Merriam Webster can be defined as something that is not clearly expressed, or stated in indefinite terms.

However, the difference is smaller in process innovation, than in product innovation, possibly due to a higher grade of complexity in process innovation. Vagueness needs to be handled separately from uncertainties in predevelopment (Frishammar et al., 2011).

4. EMPIRICAL FINDINGS

4.1. Verification

The respondents seems to have a common view that changing an existing production process such as pre-treatment, needs to follow a certain procedure. However it varies if this is described in the organization in a formal or informal way. A generalized and common process that is described by two of the organizations is described in Figure 4. It seems like the process manufacturing organization has a more distinct verification process and the discrete manufacturing organizations have a more unclear verification process.

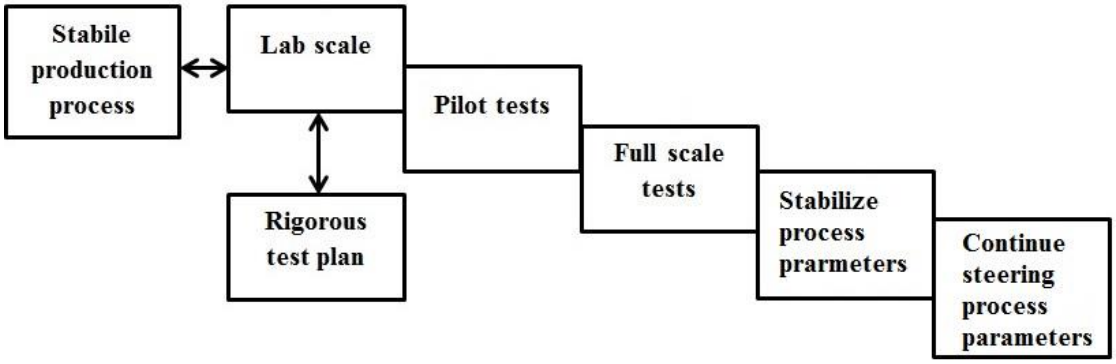

Figure 4: An "ideal" verification process described by the organizations.

4.2. Challenges

It is also clear that to organize for a common verification process, when the production processes varies, makes it difficult to maintain knowledge within the organization, which instead can be found at the suppliers. The challenges can be described on different levels showed in figure 8; variation in the work approach regarding the development of innovative processes was observed, based on the type and size of the project. Generally, the bigger the project (requiring a greater investment), the more difficult for the organization to come to a decision, many times leading to a floating, or postponed project result. A main focus on product development rather than process development is a common factor for the organizations, with the exception of the spackling paste manufacturer. The opinion of the respondents regarding the need for a common verification process is positive, as long as it's interwoven with the work flow (or method of working) of today. In all of the organizations, except the spackling paste manufacturer, the method of working seems to be depending more on the individual, rather than the organization, which implies a risk of getting a variation in the perception of the appropriate level of quality.

Along with the verification procedure there are some challenges described that relates to both the technology and the organization or both. According to some of the respondents it is technically possible to switch from phosphating to the new pre-treatment technologies on the market with no big investments. In one of the organizations the main question right now is whether the new process will be able of handling mixed materials or not, which is difficult to predict, since there is an uncertainty in which mixed materials that will be used in the future. This implies a degree of uncertainty when preparing a test plan.

To choose the appropriate test methods the requirements on the new process must be confirmed and the technical requirements must reflect the customer's demands. The ideal would be to have the opportunity to convert the customer's demands to technically measurable requirements, to facilitate the verification. Verifying a new process in manufacturing could suggest that the new process is stable and reliable enough to feel secure of the out coming product, which unfortunately rarely is the case, according to one of the respondents. Therefore, verification of the product coming out of the new process needs to be tested after a certain period of time out in the field, according to some of the other respondents. But, to be able of verifying the new process, the first question might be whether or not the correlation between "accelerated tests" and "reality" is relevant, which many of the respondents emphasized. If not, the work of validating appropriate test methods needs to be done first. A question that is raised by several respondents is; What is the "reality" of the outgoing product of the new process? In new processes where the previous knowledge is limited, there might be reasonable to accept the fact that it might not be possible to predict or test all eventuate scenarios. But what can be accepted by the customers? Relevant suppliers could probably contribute with assistance in finding or developing suitable test methods for the new process, according to some of the respondents. In an ideal situation it would be possible to use the process tests to predict the product quality. But since knowledge and experience is missing regarding the new innovative process, it is difficult to know how to steer the process parameters and interpret test results from the new process to accomplish the desired level on the product quality, according to one of the respondents. So as of today, it is not possible to rely on the test results of the process, to reduce uncertainty in testing the product quality.

To be able of making well-grounded decisions in an organization the organizational obstacles, interpersonal relationships, knowledge and test methods need to be sorted out before investigating, or developing a new, innovative process, which all the respondents emphasized.

The decision-making is a very long process, especially "when it comes to potentially expensive decisions" and according to some of the respondents "the decision-making is unclear". "Decisions are often based on the individual's gut feeling", many of the respondents claimed. "Few individuals dare to make bigger decisions, because the individual risk becomes too big, my name is on the paper, I get to take the hit if the decision later was proven to be wrong", this emphasizes the need for a clear organizational structure.

The organizational structure needs to be clarified and elaborated before initiating new process developments. Questions regarding the organizational structure were an iterating theme among the respondents, from all the studied organizations. In some of the organizations there are proactive models upcoming, but far from finished or implemented as of today, often due to prioritization of more short-term investments and a lack of resources.

Where the process development is sorted in to the functional structure of the organization can also have significance to the outcome. Working communication seems missing between the different functions in some of the organizations, which could be caused by insufficient relationships and networks, both internally in the organizations, but also between different organizations. Cooperation is seen by the respondents as a way of increasing communication,

and strengthen relationships. Some of the respondents have experienced a negative attitude towards their knowledge and creativity, which has excluded them from contributing to the development of innovative processes, therefore it is important to include the personnel working in the production process on a daily basis, also in new development projects.

Knowledge of the current manufacturing process as well as the development process is seen as required for verifying innovative processes, by the respondents. It seems as, experience is highly considered by the respondents, of the new process under development as a facilitator of success. To have awareness of the customer's needs, wishes and demands is vital for creating value, which is one of the definitions of an innovation, is also mentioned. "If we do not know what we have today, we cannot know what determines if the innovative process will work and deliver the desired results", said one of the respondents.

According to the respondents standardization documents are a common ground for proper verification of innovative technology, if the standardization documents are formulated cleverly and used in combination with common sense. According to one respondent, some standardization documents contains instructions on how to steer and control a specific process, which becomes to extensive and inhibits technical innovations concerning process development. According to another respondent, different standardization documents for one product contradict another requirement in another standardization document for the same product.

To facilitate a systematic approach within the organizations, the standardization documents could be a tool, this requires that all the standardization documents harmonize with each other, so that no contradictions occur. It is also necessary to find an appropriate level of detail in the standardization documents, so that they do not steer the work in detail, but do not leave to much room for variation.

4.3. The statements of intent

The statements of intent for VCE are based on the findings from the interviews and the participant observations. The statements of intent describe how the verification of innovative pre-treatments can be done, what needs to be taken in to consideration and which factors needs to be settled before initiating the verification. Guidelines for prioritization of the activities are also included. The statements of intent are based on the verification process proposed earlier in this report, see figure 5. Due to secretes, the statements of intent cannot be presented in detail in this report, and they are only available for VCE.

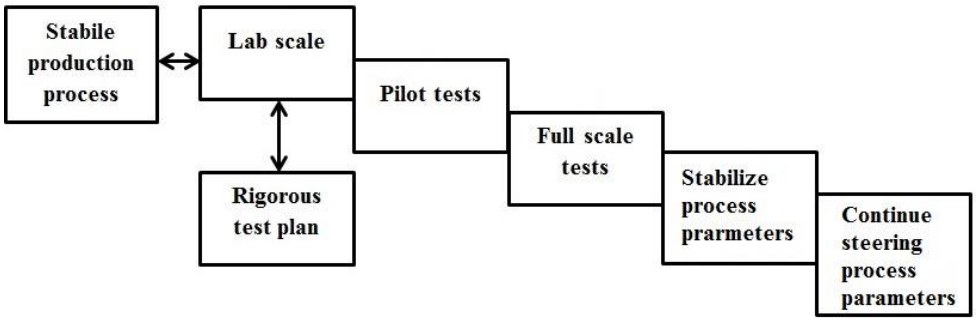

Figure 5: the base for the statements of intent.

4.4. The conference article

As a result of the multiple case-study, a conference article was written by this author in cooperation with Anna Sannö (my mentor at VCE and INNOFACTURE, MDH) and Anders Fundin (professor in Quality Technology and Management at Innovation and Product Realization, MDH). Hopefully this article will be accepted for publishing and presentation at the Swedish Production Symposium 2016 (SPS'16).

5. ANALYSIS

After compilation of the results of the multiple case-study, some figures were constructed, to facilitate the analysis of the results, see figure 6 and 7.
Figure 6 shows where the challenges occur in the manufacturing process, this is based on the information of the respondents, where having a stable and robust manufacturing process is a very important presumption, before being able of implementing new innovative production processes. Because, if you do not know what you have today, and how it affects the product quality, you cannot be sure of how the new process will meet the requirements. Grasping, and maintaining a holistic perspective is one of the bigger challenges, perhaps due to many involved individuals within a wide range of functions, with a variation in mission and resources. Organizational challenges are a recurring theme among the respondents, which implies that this might be a reasonable area for the companies to put extra focus on, especially since the organizational challenges affect all areas. In acquiring appropriate test methods for the verification process, the supplier could be a suitable guidance, if knowledge within the organization is missing, according to the respondents, this matches the results of Geffen & Rothenberg (2000). Cooperation with suppliers in developing and implementing innovative processes is also a key to success, according the respondents as well as Geffen & Rothenberg (2000). Standardization documents and a systematic approach to verification is an iterating challenge across the organizations, but can also function as an enabler, if used in a different way. The studied organizations seem to have difficulties making decisions regarding on how to verify new, innovative processes, which seems to be caused by a lack in experience and knowledge in how these processes "behaves" and what the results and consequences might be. Regarding pre-treatment processes, these are often supposed to maintain the required level of quality for a very long period of time, at the use of customers in a varying range of situations and environments, which ads a level of complexity in the verification process. The pre-treatment is also supposed to work with different substrates and other types of surface treatments, such as primers and top coats, new components are under development, which increases the uncertainty.

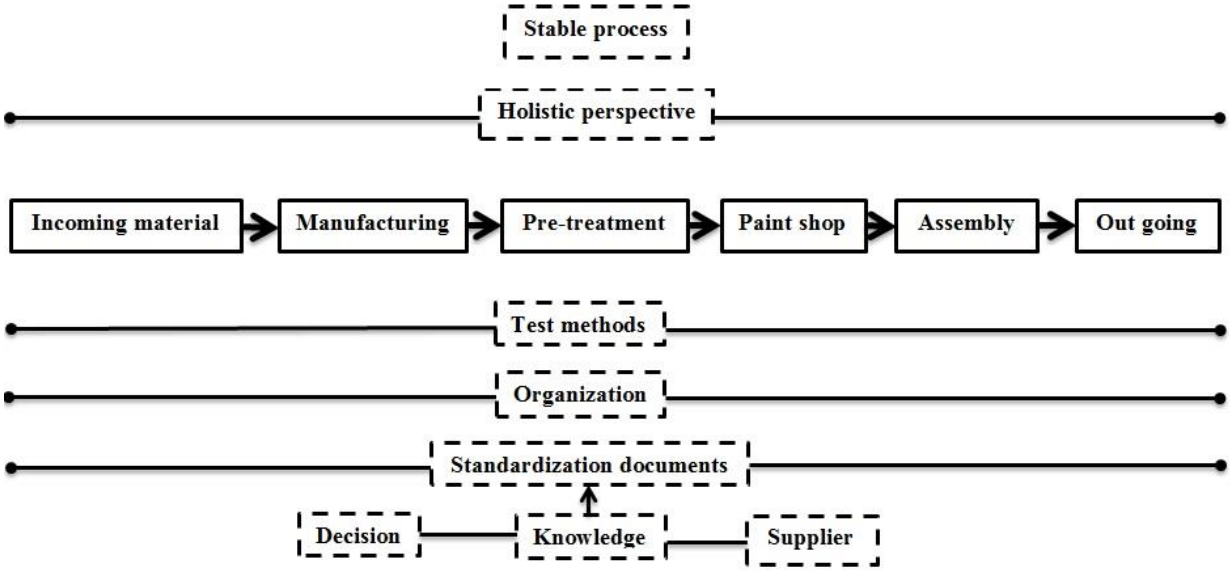

Figure 6: showing where in the manufacturing process the challenges occur.

Previous research within the area has many times focused on external challenges, rather than internal challenges. Examples of external barriers are; legislation and low public pressure

(Mittal & Sangwan, 2014), which implies that this study is contributing with results useful in covering a gap in the research.

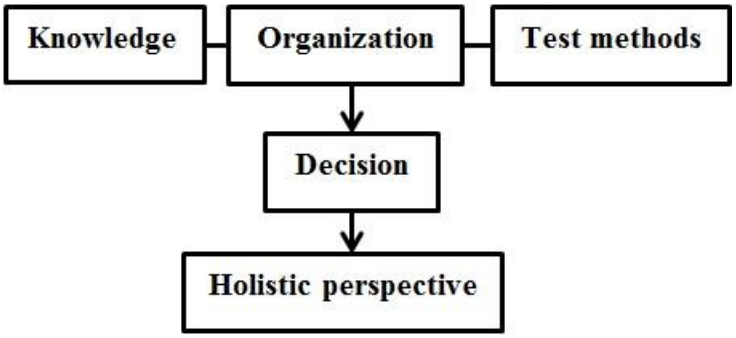

Figure 7: Enablers

In figure 7, the enablers found in the study is shown, where knowledge, the organization and test methods are the main enablers for organizing for a verification process, and facilitate decision-making and maintain a holistic perspective. This figure was very useful for the author, when connecting “the dots” found in the data collection, which clarified the potential relationship between the enablers.

6. DISCUSSION

The results imply that it is important to take a holistic perspective when a technological change should be conducted. A holistic perspective could be useful in enabling decision-making. "Unmanageable if no one pulls forward", said one of the respondents about the conceived lack of a holistic perspective. Where organizational obstacles, knowledge and test methods are important pieces in the holistic perspective.

Aligned with the findings of Frishammar et al. (2011) vagueness and uncertainty is of importance when verifying innovative processes, but should be handled separately. The study indicates that uncertainty is related to variation in the production process and vagueness in the organization is connected to variation in the projects.

The challenges regarding the uncertainty in variation in production processes is technical risks and test methods. Eventual consequences connected to an innovative process might be unknown, and therefore it might be difficult to know which test methods that are appropriate. Challenges connected to vagueness originate from the variation in projects and these are decision-making, organizational challenges and intrapersonal challenges. Unclear organizational structure with fuzzy objectives, weak intrapersonal relationships and communication makes decision-making difficult.

Variation in the work procedure regarding the development of innovative processes was observed, based on the type and size of the project. Generally, the bigger the project (requiring a greater investment), the more difficult for the organization to come to a decision, many times leading to a floating, or postponed project result. A main focus on product development rather than process development is a common factor for the organizations, with the exception of the spackling paste manufacturer. The opinion of the respondents regarding the need for a common verification process is positive, as long as it's interwoven with the work flow (or method of working) of today. In all of the organizations, except the spackling paste manufacturer, the method of working seems to be depending more on the individual, rather than the organization, which implies a risk of getting a variation in the perception of the appropriate level of quality.

The challenges of process innovation when implementing a new pre-treatment line in the case study setting seems to depend on variation related to either production process or different projects. The production process itself creates an uncertainty when to discuss if the alternative technology works in the actual setting and if it will withstand the standards and existing tests. The project variation comes from the degree of changes, if there is a project that involves organizational change, technological change and if investments are needed. Based on the empirical finding and the importance of managing uncertainty and vagueness (Frishammar et al., 2011) the following model of challenges is presented, see Figure 8.

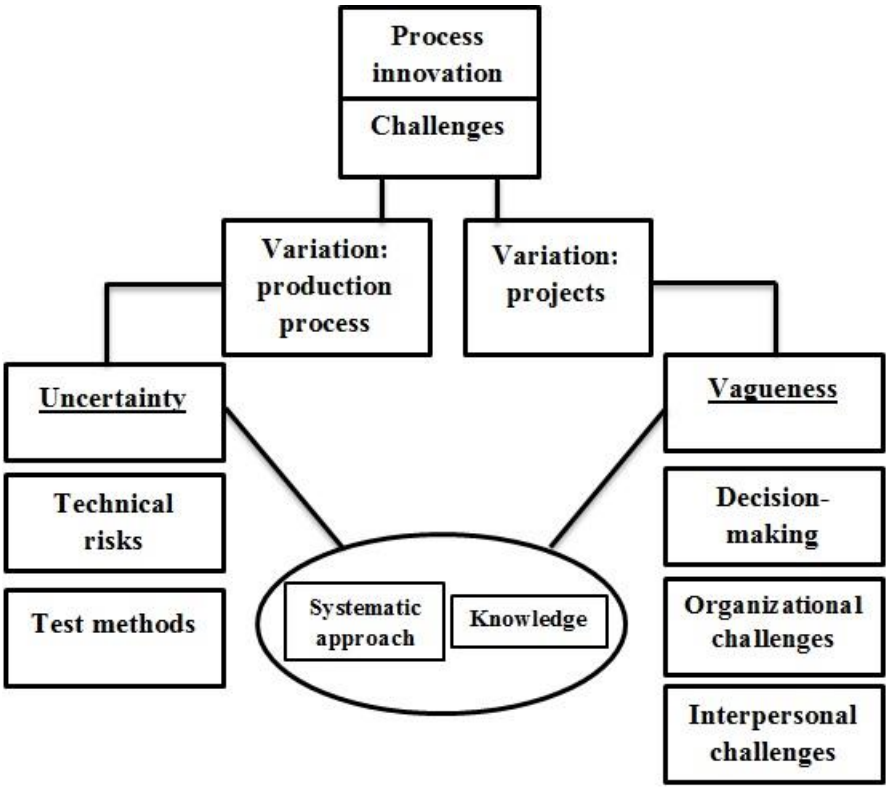

Figure 8: Challenges in a verification process.

It is also clear that the respondents consider the technical change possible to conduct without major challenges; however the organizational changes such as decision making and risk taking are harder to overcome. Vagueness in the organization can lead to uncertainty in the verification process. The vagueness could be enabled by making knowledge explicit about the existing and new production process as well as making sure that interpersonal collaboration, communication and relevant networks are considered when managing the project. It is therefore important to have a transparent process for verification by understanding the actual outcome of test methods. When to organize for a common verification process, when the production processes varies, it becomes difficult to maintain knowledge within the organization, which instead can be found at the suppliers, which corresponds with Geffen & Rothenberg (2000).

The model for innovation-decision process by Rogers (2003) can be used to reflect the work flow, where the systematic approach could be useful for enabling the challenges regarding knowledge, persuasion and decision-making, see figure 9. However, this needs further examination before eventual implementation of the proposed modification.

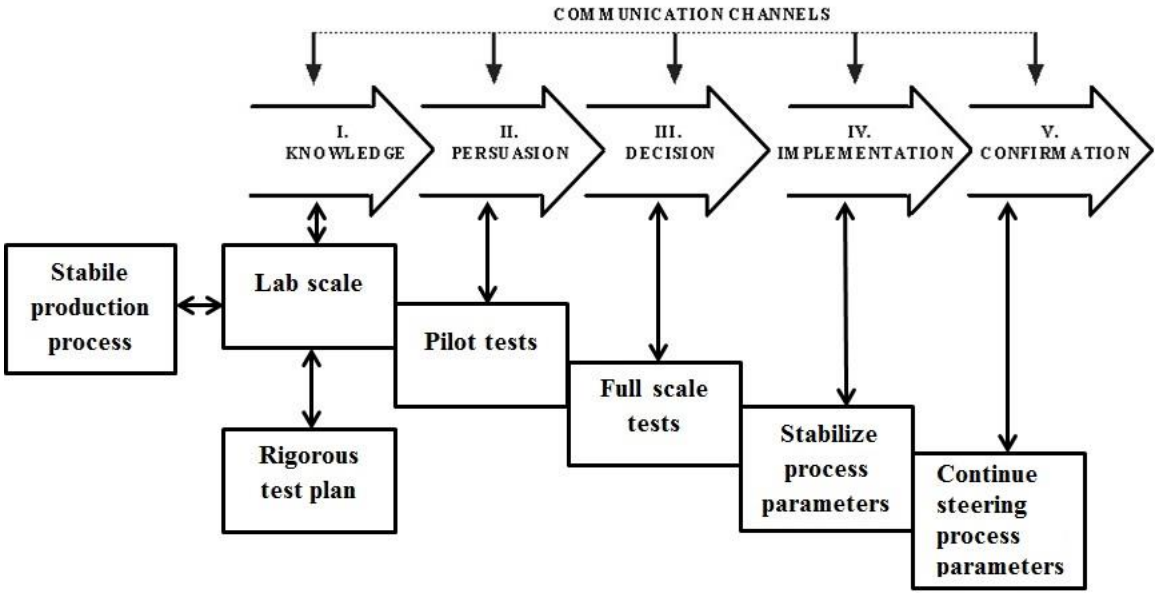

Figure 9: Proposed modification of model for innovation-decision process.

7. CONCLUSIONS AND RECOMMENDATIONS

This report describes the challenges of process innovation when verifying production processes adapted to new environmental requirements. The study shows how implementation of environmental conscious manufacturing and the organizational change can relate to the technological risk (Mittal and Sangwan, 2014). The challenges relate to both technological and organizational changes (Ettlie et al., 1984, Rogers, 2003) and relates to both uncertainty and vagueness (Frishammar et al., 2011).

When adapting production processes to new environmental requirements the focal point is to grasp and maintain the holistic perspective over the entire verification process, from incoming material, through the production process to outgoing products.

The incoming material to the production process also addresses the supply chain management, which includes all units in the organization, including the suppliers, where the enablers are good communication, positive relationships/ networks and clear goals and purposes.

A well-structured, transparent verification process, with stabile production process parameters and test methods throughout the production process sets the standard for the quality eventuate together with solid knowledge/ experience of the plants conditions.

To verify new technology a holistic perspective is crucial, where the organization, communication and knowledge are the main enablers, which require a unanimous long term perspective to where the organization is heading regarding new technology, to minimize uncertainty and vagueness and by that enable decision-making.

For practice it is important to manage vagueness, by early raising questions about: who is authorized to make decisions, responsibilities, vision and strategies and prioritization.

The study shows how barriers of technology risk when implementing environmental conscious manufacturing can be related to the verification process and contributes by giving understanding to the actual challenges companies can face in the adoption to environmental conscious manufacturing.

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9. DEFINITIONS/ WORD GLOSSARY

Knowledge: the fact or condition of knowing something with familiarity gained through experience or association.
Communication: a process by which information is exchanged between individuals through a common system of symbols, signs, or behavior.
Organization: an administrative and functional structure (as a business or a political party); also: the personnel of such a structure.
Interpersonal: Being, relating to, or involving relations between persons.
Decision-making: The act or process of deciding something especially with a group of people.
Holistic perspective: Relating to or concerned with complete systems rather than with individual parts.
Standardization: To bring into conformity with a standard.
Verification: The process of confirming or checking the accuracy.
Process: a series of actions that produce something or that lead to a particular result. (Merriam Webster, 2016)
Process manufacturing: Production that adds value by mixing, separating, forming, and/or performing chemical reactions. It may be done in either batch or continuous mode. See: project manufacturing (APICS dictionary, 2016).
Discrete manufacturing: The production of distinct items such as automobiles, appliances, or computers (APICS dictionary, 2016).