Information System management in New Space production

Adapting a low volume-high quality production's information management system

Master's thesis in the Production Engineering Programme

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CHALMERS UNIVERSITY OF TECHNOLOGY
Gothenburg, Sweden 2020
www.chalmers.se

MASTER’S THESIS 2020

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Master’s Thesis 2020
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Cover: The cover picture is taken from RUAG Space AB’s website, provided for commercial use.

Printed by Chalmers Reproservice
Gothenburg, Sweden 2020

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Abstract

With the emergence of New Space, the space business environment has become more dynamic, more rapidly changing and involves more risk taking for space goods manufacturers. For the space manufacturers to survive in this new environment and gain competitive advantages, they must meet the requirements of New Space production: Lower costs, lower lead times, higher production flexibility, and higher responsiveness to the changing business environment. One important aspect that facilitates these requirements, is how the information is managed in the organization.

To find what aspects to consider in information management from a New Space point of view, a literature study was combined with a case study. The results showed that there are 7 aspects of information quality more important than other to considerate in an IS in a New Space organization. Those 7 aspects were Accuracy, Communication & Cooperation, Timeliness, Completeness, Amount of Information, Accessibility & Findability, and Consistency. The results also showed that the implementation of these aspects into the IS could be done via Standardization and improved Data transfer. Customization of the IS was also suggested to be beneficial if done right.

The findings resulted in a list of suggested implementations the case company, or other companies in the same situation, should consider. These suggestions embodied the findings of this research. If the 7 aspects are considered, and if they are implemented through standardization and improved data transfer, companies in the New Space sector will have a much higher chance of reducing costs, lower lead times, raise their production flexibility, and raise their business responsiveness, and by this be competitive on the New Space market.

Keywords
Information quality, New Space, Information system, ERP, cost, lead times, flexibility, responsiveness, standardization, automation.

Acknowledgements

I would like to express my sincere gratitude to my supervisors Dan Li and Malin Tarrar at Chalmers University of Technology for guiding me and supporting me through this project, and Magnus Årebo at RUAG Space AB who with unfailing enthusiasm helped me with every on-site question and concern I had. I would also like to thank all other *temporary colleagues* I had at Ruag who supported me with tremendous help and made me feel very welcome, and the authors of this project's sister project who went through the same ups and downs writing a master thesis entails, and who offered social as well as practical support through this adventurous research process. Finally, I would like to thank my family and my friends for their endless support, ever so important in times like this.

Klara Holmgård

Gothenburg, June 2020

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Abbreviations

IS – Information system

ERP – Enterprise resource planning

PCB – Printed Circuit Board

M&P Engineer – Material & processes Engineer

IQ – Information quality

1 Introduction

This first chapter introduces the reader to the thesis by giving a background to the research topic, the aim of the research with the research questions, along with a description of the company where the case study will take place - RUAG Space AB. Last but not least, the delimitations taken in the research will be presented.

1.1 Topic Background

In the last decade, the space industry has gone through a fundamental transformation with the emergence of a new business market sector - New Space. Traditionally, the space market has been composed of government funded projects created on political and military basis aimed for defense and military advancement, or projects created and driven on a more scientific research basis (Vernile, 2018), aimed for weather tracking or GPS mapping, for example. Companies inhabiting this market can usually be characterized by having production of custom-made space goods with impeccable quality, where the volumes are as low as one up to a few dozen products, and the work is performed to a highly manual degree (Larsson, 2016).

Today, this oligopolistic market has opened up to the private sector under the name New Space, who are seizing the opportunity to create new, commercial, space bound services for, for example, telecommunication, Internet of Things, and worldwide connectivity. To provide these services, low-Earth orbit satellites connected in big constellations consisting of up to 12,000 satellites are being used (Ritchie, 2019). This shift in market provide the traditional space companies with great opportunity to expand their business and seek revenue in, to them, new territory, but at the same time they face many new challenges (De Concini & Toth, 2019). New Space production entails new production demands, such as increased flexibility for fluctuating production volumes, decreased costs, decreased lead times, and an increased organizational responsiveness. While the traditional space manufacturers might have superior technical expertise compared to new, commercial companies, they lack the experience of this kind of low cost-high flexibility production that New Space production requires.

One critical element supporting this new kind of production is the production data and information, and the management of it. The information system (IS), the system that collects, stores, and distributes the data and information in an organization, can impact productivity, project duration, decision and product quality, business flexibility and overall costs, and by this bring highly competitive advantages (Altamony et al., 2012). With the increased production complexity New Space production entails, where the key driver no longer is only product quality and reliability, but the several more [above mentioned] factors, the need of an IS that can manage this higher complexity is essential (NRFP, 2016). The functions and aspects needed in an IS is highly contextual, though (Lee et al., 2002; Wang & Strong, 1996). A quick search on any multidisciplinary research database shows that much research have been conducted on general information management, information quality, and information management and IS in well-established business areas, but the research covering the application of IS in New Space organizations is yet to be conducted. This motivates new research on information management in a New Space production environment, that will broaden the knowledge about information management, and serve as a guideline for organizations wanting to adopt the New Space production characteristics.

1.2 Aim & Research Questions

Based on this background, the aim of this project was therefore to contribute to the theory of how information should be managed in a production environment used to involve low volume production done to a highly manual degree, that wants to turn towards a production environment that meets the demands of New Space production. To fulfill this aim, two research questions were created:

RQ1: What information functions and aspects are needed to fulfill the requirements of New Space production?

RQ2: How can an information management system in a company standing before this transformation be adapted to support the transition towards New Space production?

1.3 Delimitations

The area of IS and the management of it is broad and multidisciplinary, which makes it important to limit the scope of the research. In this research, the IS and the theory behind will focus on the application to the part of the production and manufacturing that stands before a transformation process towards, or already somewhat fulfills the characteristics of New Space production. The project will also only cover the manufacturing company, and not the supply chain connected to it, and within the case company, the project will focus at the information functions and aspects regarding the information in itself, and not the practical visualization of information or system interface.

Further, this project focus on the technical aspects and not the sociotechnical or strategic ones. Such aspects, for example cultural business behavior, manager support, the connection between IS and KPIs and corporate goals and objectives, is an area that already has been covered to a great extent. Therefore, focus will be on the less covered area of the technical information aspects.

The thesis will result in a list of recommended improvements, but the improvements will not be implemented in the case company or any other company in this research. This will serve as a basis for future research, discussed in the end of the thesis.

1.4 Case Company

One company that is experiencing this market shift is RUAG Space AB. The case study was conducted on the company’s production site in Gothenburg, Sweden, which employs around 280 people, and produces microwave, antenna and digital units aimed for space usage. With 20 years of experience of development and production of space technology for the traditional space market, they are one of the market leaders in Europe, and on the rise in the United

States. Their production's characteristics are job shop assembly with a high degree of manual work, with long lead times, high product customization, high quality and complexity, and low volume production.

Data and information in the company are almost exclusively collected manually and stored in multiple external sources. In 1998, they adopted an ERP system, a system that is connected with mixed feeling in the company. Other examples of sources are their intranet, e-mails, physical and digital meetings, whiteboards, and spreadsheets.

Their customer focus has shifted over the last couple of years. In 2017, approximately 34% of RUAGs products was delivered to the public sector, and 66% to the private sector. Bärring (2017) estimated in a collaborative project between RUAG Space and Chalmers University of technology, that the production volumes to the private sector was estimated to increase with 400% within the coming years. For RUAG to be able to meet that forecast, they must further shift their focus towards the private customers, and by doing that they have to face the customer demand of the New Space market.

In 2018, another collaborative project was conducted between Chalmers University of Technology and RUAG Space Gothenburg, by Olofsson and Orstadius (2018), where a mapping of the currents state production was done, including simulations using different volume scenarios. This mapping resulted in the insights that RUAG does not meet the demands of New Space production, and that, among other factors, a higher level of automation is needed along with better means for cooperation between the product units, and that further studies on how the information management system can support the fulfillment of the production demands should be conducted.

2 Frame of Reference

This chapter provides a theoretical framework that introduces the reader to the concepts of information and information quality (IQ), how it is used in IS, and also the requirements New Space production entails.

2.1 Information and Information Quality

Reynolds (1992) describes information as *"the data that have been refined and organized by processing and purposeful intelligence",* that is data, that can be in the form of raw, unorganized numbers and facts, that have been processed and given a context in order to make it useful for someone or something. An example could be a list of temperatures, data, that in itself is more or less useless, but put in the context of the temperatures representing different stages in a curing process for example, the data becomes understandable and useful, and thereby turns into information. An information system – IS - processes data to information, stores and administrates it, and presents it to its user (Ehikioya, 1999).

With technology advancements, the ever-expanding access to data and information, the rise of *Big Data*, etc., storing and managing information is no longer enough, the quality of the information in an organization is becoming more and more critical. High quality information can be described as information that meets the users' needs and adjust to the specifications put on it by considering different IQ aspects. Although, what those aspects are depends entirely on the contexts the IS exists in (Lee et al., 2002; Wang & Strong, 1996).

On the other side of the spectrum, the concept of information waste can be found. The concept builds on Lean philosophy's production wastes. Marttonen-Arola & Baglee (2018) identified information waste in a manufacturing context by comparing information aspects with the traditional Lean wastes, resulting in a list of 8 information wastes presented in Table 1.

Table 1. Information waste, identified by Marttonen-Arola & baglee (2018)

Information waste
1. Unnecessary data in decision making
2. Unnecessary data in other parts of the process
3. Unnecessary transfer of data
4. Waiting for data
5. Unnecessary processing of data
6. Incorrect data
7. Incorrect analysis
8. Underutilized data management resources

Summarized, these waste aspects relate to excess information, over processing of information, and poor data quality. By not considering these aspects, the result could be lost productivity, delays, errors and rework entailing high costs and resource consumption, unnecessary system and production complexity, and confusion and frustration of the system users (Bell & Orzen, 2011).

2.2 Information Systems

Like Ehikioya (1999) described, an IS is designed to collect, interpret and process, manage, and distribute information in an organization. As defined by O'Brien (2003), an IS can be any form of organized combination of data resources, ways of communication, policies regarding information management, people, and technology. Today, in the production sector, an IS commonly takes the form of a computer software system that provides the data and information necessary for controlling the performance of the organization (O'Brien, 2003).

There are different types of computerized IS, but Zhang et al (2005) among others describe Enterprise Resource Planning (ERP) systems as the most common option for production companies seeking to obtain competitive advantage. An ERP system is a software system that provides an integrated way of managing a business, combining previous individual IS, manufacturing systems, finance systems, etc., with the benefits of providing automated business processes, real-time access to data, and supply chain improvements (Yusuf et al. 2004). It is comprised of different application, where information submitted into one application should automatically update any related information, discarding the need for submitting the same data more than once (Davenport, 1998).

But the competitive advantage is highly dependent on how well the system considers the information aspects connected to the organization it is implemented in. When implemented correctly, the ERP system can significantly impact the users own productivity as well as the organizations productivity, decrease the time put on decision making while at the same time increase the quality of the decisions, facilitate information sharing and cooperation between the different units in the organization, and bring competitive advantages (Zhang et al., 2015). If implemented incorrectly, the ERP can instead entail large implementation and maintenance costs, less flexibility in the organization, and in the worst-case scenario, shareholder lawsuits, company meltdown and bankruptcy (Fruhlinger et al., 2020). Therefore, it is of utter relevance that any organization that seeks to implement or improve their IS identifies which aspects of information quality they should focus on.

2.3 New Space

Between the years 2006 and 2012, a shift in the space market could be observed. The shift entailed going from producing satellites by traditional production methods, to a production style based on entrepreneurship, agile manufacturing, and that did not have to rely on governmental support. The new style also went from only including the few, well established, space manufacturers that rose in the early Space Race days and since then have dominated the space market, to include new actors, for example electronic manufacturers or communication providers (Venezia et al., 2019). This, what first was called Alt.Space – an alternative way of doing space (Martin, 2014), later came to be called New Space. The line between New Space and Old Space is not a straight one though. Martin Sweeting (2018), one of the world's leading professors of space engineering, defines New Space as *"the emergence of a different ethos for space where the established aerospace methods and business have been challenges by more entrepreneurial private sector by adopting more agile approaches and exploiting the latest commercial-off-the-shelf technologies"*. By that definition, the origin of New Space can be credited to CNES in 1982 with their commercial earth observation technology Spot Image was created (Denis et al., 2019). The definitions also show that New Space is not a physical set of market actors comprised of private companies either, but more of a production and business philosophy. If the traditional, well established, space companies adopt the New Space production approach, they also become part of the New Space sector.

2.3.1 New Space Production

Traditional, Old Space, production of satellites and other space goods, can be characterized by astronomical budgets, long project timeframes including only a few missions, complete product reliability, and a more or less indifference to the changing business environment influencing the rest of the world economy (Koechel & Langer, 2018). The production itself often consist of highly manual work, with batch sizes of one to a few dozen products.

New Space production can instead be characterized by lower costs, shorter timeframes, a high responsiveness to the changing market requirements, a more commercial customer focus, and a higher willingness to taking risks (Pawlikowski et al., 2012). These attributes can be realized by the usage of low-Earth orbit satellites connected in big constellations, the batch sizes can be of several thousand products (Ritchie, 2019). To meet all these customer demands; high volumes, low costs, short lead times, still high quality; production costs needs to be cut in order to meet the more limited financial funds allocated based on profit, the flexibility to changing production volumes needs to increase, the development cycles and lead times needs to be reduced, and the responsiveness of the production needs to be generated through the right, support, business models and organizational structures (Koechel & Langer, 2018). More concrete, this can be realized through the employment of mass production techniques such as standardization, modularization, and increased levels of automation, where the management of production data and information relating to these processes plays an important role (Olofsson & Orstadius, 2018).

3 Methodology

This chapter presents the methodology that was used in this research. A multimethodology approach was used where a structured literature review was combined with a case study, by Mingers and Brocklesby (1997) described as *Methodology enhancement* which amounts to “Enhancing a methodology with techniques from another”. The methodology was further enhanced by using a mixed-method approach when analyzing the findings in the literature study and the case study, including a quantitative analysis of the findings, and a qualitative analysis of the meaning of the findings. The literature study and the case study were performed parallel to each other in order to minimize any biases and preconceptions of the researcher that could occur from finding the result from any of the studies. Then, a comparison of the findings from the literature study and the case study was done in order to connect the theoretical findings with the real-life scenario, and conclusions based on the comparison were drawn. A schematic representation of the methodology followed is presented in Figure 1.

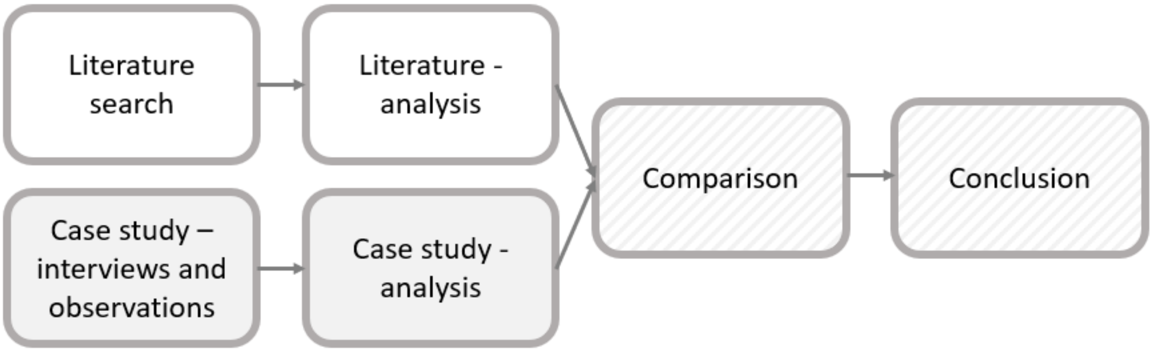

Figure 1. Schematic representation of the workflow.

3.1 Literature Review

For a study to be successful and of good quality, it is important to have a thorough understanding of the previous research conducted in the area (Saunders & Rojon, 2011). Webster & Watson (2002) credits the literature review to the provision of a firm foundation from which to advance the knowledge of a topic. The IS field are by now a well-established research field with a lot of empirical and theoretical research connected to it, but since the success of an IS is highly dependent on its context, and the advancement of technology provides new contexts every day, continuous reviewing of the area in order to advance the knowledge is needed. To create a foundation for this thesis, with the specific goal of finding knowledge regarding IS management in general, and IS management targeting the characteristics of New Space production in particular, important factors and models, and finally answer research question no. 1, a literature review was therefore done.

The literature review was organized according to Figure 2, following the guidelines suggested by with Tranfield et al. (2003), and was conducted by combining keywords based on the research questions, analyzing the literature found in the searches, combining the finding, and analyzing the results based on the perspective set in the research questions.

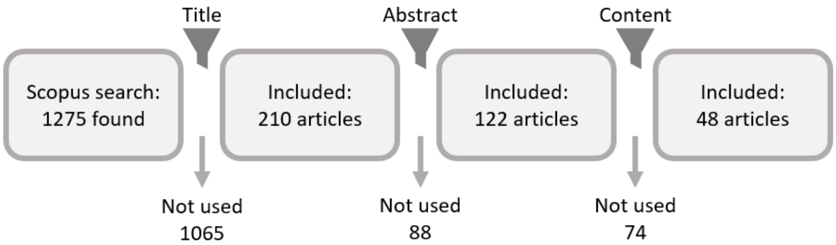

Figure 2. The process of the literature study, further explained in the following text

The multidisciplinary reference database Scopus was used for the literature searches. Based on the aim of the literature search, and the research questions, the keywords were chosen to focus on IQ aspects and similar factors for an IS, and were combined by Boolean operators. Since IS can be found across all types of fields and the term varies in definition depending on what field it is used in, delimitations were made to only focus on IS implemented in manufacturing and production environments. This was done using the *"limit-to"* function, which was set to only include articles published in the business and management field in order to avoid irrelevant hits on for example IS implemented in hospitals and nursing, the more technical articles written about the programming behind the IS, articles where IS means something completely else, but also articles focusing on IS implemented over the whole supply chain which are relevant for the business and management field but not part of this thesis. The search was further limited to articles written in English. As to not limit the search too much, after some initial testing, some synonyms were included, the full search string used was:

TITLE-ABS-KEY (("information quality" OR model OR factor* OR "information management" AND NOT supply AND chain) AND ("information system" OR is OR mis OR "erp system") AND (production OR manufacturing)) AND (LIMIT-TO(LANGUAGE, "English") AND (LIMIT-TO(SUBJAREA, "BUSI"))*

e.g. *IQ aspects and IS in a production environment*. This search resulted in 1275 potentially relevant articles.

Following Pilbeam et al.'s (2012) guidelines regarding literature screening, the documents were then evaluated on relevancy based on their title. The inclusion criteria in this screening was to focus on articles which in their title mentioned IS in production or manufacturing, IQ, ERP implementation, other information and communication technology, or had such open and general titles that they could not be dismissed right away. This screening resulted in 210 articles remaining. Then, a review of the remaining articles' abstracts with the same inclusion criteria was done, which resulted in 122 documents remaining. Finally, after swiftly reading through the remaining articles, a last screening was done. This time, it was possible to in the inclusion criteria sort out articles that only focused on the more sociotechnical aspects of IS management, such as change management, cultural business behavior, management support, and also articles that showed to focus on pre-IS implementation conditions. This resulted in 48 articles remaining that consisted of technical IS success factors, ERP case studies, and IQ in production research, that were then studied in-depth.

The articles were then summarized with keywords corresponding to functions and spects most important for an IS. When factors were found matching the conditions for New Space production specifically, these were noted down in short text. The keywords where then summarized in two tables visualizing who and how many of the authors that found the different aspects important, and following the tables comes an explanatory text that digs deeper into the different aspects and described the authors motivations behind the aspects and their relation to New Space production criteria.

The two tables were divided into one table that shows aspects of an IS from a theoretical, IQ viewpoint, and one table that showed practical IS functions that could be deployed to fulfill the technical aspects. For the table showing the theoretical IS aspects, all aspects mentioned more than 5 times by different authors are included in the table, the rest that were mentioned less than 5 times but still deemed important were summarized in the following text. For the table showing the practical IS function, all functions mentioned more than 3 times by different authors are included in the table and functions mentioned less times but still deemed important where summarized in the text following that table. How these information functions and aspects were connected to each other were also visualized.

3.2 Case Study

In order to provide an understanding of how the findings from the literature study relates to a real-life context, a research case study was performed, an approach commonly used for research within the IS discipline (Shanks & Bekmamedova, 2018). The reason for its popular usage is because it enables the researcher to focus on the dynamics of the system and the contemporary phenomenon connected to it in a single setting, including the users experience of the IS (Eisenhardt, 1989). Another reason for choosing the case study approach is because the IS are fused to the organization they are implemented in and cannot be separated from their organizational context (Markus & Robey, 1988).

The aim of the case study was to identify how the IS was designed and used in the case company, and to identify problems with its implementation and gaps in the information flow from a New Space production point of view. By this, a deeper understanding was hoped to be found regarding how IS should be implemented in a New Space production environment, and ultimately seeking to answering research question no. 2.

The case study consisted of semi-structured interviews, and observation of the system and revising of documents in it. By using different data collection techniques and combining qualitative and quantitative analysis methods, different interpretations can be combined, and a broader understanding can be gained which strengthens the credibility of the result of the case study. This combination is called triangulation (Flick, 2014). Following is a deeper accounting of the methodology for the interviews and the observations.

3.2.1 Semi-Structured Interviews

To collect qualitative data and add to the empirical understanding about the IS user's information needs, their conception of the system, and any relating problems, semi-structured interviews were conducted. The interviews were performed face-to-face in order to be able to observe any non-verbal indicators occurring when discussing the problems with the IS, and to motivate the interviewees to participate as fully as possible since questionnaires or written interviews can limit the responses obtained which is unwanted when having a small interview sample (Barriball & While, 1994). The interviews followed an interview guide consisting of predetermined questions but allowed large flexibility for discussion in order to get as open and conversation-like answers as possible. Adams (2015) describes semi-structured interviews as a combination of standardized, close-ended surveys seeking specific answers, and free form, open-ended interview sessions seeking to explore uncharted territory. The combination results in a method that can both mender around specific questions via closed-end questions, and explore on beforehand unforeseen issues by asking follow-up or open-ended questions. Since the aim of the interviews was both to find the users specific needs, and also their more general perception and thoughts about the IS, the semi-structured interview approach was chosen.

A small variety of IS users were interviewed, divided over different but adjacent roles in the company, presented in Table 2. The interviews were held in Swedish so that no language barriers would influence the answers (Barriball & While, 1994). The interview guide, in the original Swedish and translated to English, is presented in Table 3.

Table 2. Interview participants and their roles in the organization

Interviewees - Roles	**Number of participants**
Project manager	2
Object manager	3
Material & Process/Quality engineer	2
Production technician	2
Layout engineer	2
Total	**11**

Table 3. Interview guided used in the semi-structured interviews

Questions – Swedish (original)	**Questions – English (translated)**
1. Vad har du för roll och arbetsuppgifter?	What is your role and your work tasks?
2. Vilken information behöver du, var hittar du den, vet du vem som skapat den/var den kommer ifrån?	What information do you need? Where can you find it? Do you know who owns it or where it comes from?

3. Vad gör du om du inte direkt hittar den information du behöver?	What do you do if you can't find the information you need?
4. Vilken information skapar du, hur förmedlar du den och vet du vem den är menad för?	What information do you create? How do you distribute it? Who is it meant for?
5. Behöver du göra några uppskattningar eller antagandeden? Varför?	Do you have to do any estimations? Why?
6. Upplever du eller har du observerat några andra problem i samband med informationshanteringen inom företaget?	Have you perceived or observed any other problems with the information management in your company?

3.2.2 IS Observations

To add to the result from the interviews, a participatory system observation was performed, by the researcher taking on an *insider role* and using the system herself, as described by Williamson (2018). The observation was conducted by using the system and studying the available functions in order to get and understanding of how the IS was implemented and used, and to find any problems relating to the information functions provided. Documents and reports in the system were also studies and analyzed with the same aim. The documents consisted of quality and constrain documents, work instruction, information flow descriptions, among others.

3.3 Cross Combination

After the literature study and the case study were conducted separately, the results were compared to each other as described by Miles et al. (2013), with the aim of finding areas the case company needs to improve in in order to meet the New Space production demands, and possibly find practical ways of doing this.

This was done by using the finding from the literature study as a base for which the results from the case study was compared with, where the problems perceived by the interviewees and those found in the observations were described in terms of the aspects found in the literature review. The connections between the literature findings and the case study findings were presented in a cross-tabulation matrix, that showed which roles that found which aspects important. The aspects were then further discussed around the gaps found in the case company's information management and suggestions from the literature for how to fix them.

In the following chapter, *6. Discussion*, the implications of the cross analysis on the production were discussed, and suggestions for improvements that the company should undertake were given. Additional connections between the theoretical IS aspects and the practical IS functions could also be made based on the findings of the case study.

When comparing the literature study with the case study, all aspects were viewed as equally important, since no correlations could be drawn over which aspects that influence the New Space production demands the most. In the discussion on the other hand, focus was put on those information management areas and aspects that was furthest away from being reached, since the aspects were interpreted to be concatenated and therefore the conclusion was drawn that it is better for the organization to improve and become better in in many areas, than to only make one area perfect.

3.4 Validation of Results

Kim & Peterson (2001) describes that the users of an information system often are the people that have the clearest view of how the system works, and what information aspects are important in their work and their organization. Therefore, Kim & Peterson argues that the users' perception is a good face validity. One way of using the users to do the validation, is by member checking. Member checking is a good validity technique for qualitative studies, and amounts to validating that the data collected during an interview and the interpretations from an interview are correct, or validating that emerging findings and conclusion drawn based on an interview are correct, by collecting feedback from the interviewees (Harvey, 2015). In this research, the member check was performed in terms of the second example.

So, to investigate whether the suggestions made based on the results in this project would improve the problems, and if they were implementable at all, member check interviews were conducted with 2 of the interviewees. The member check was performed by the researcher reviewing the results of this research together with some of the interviewees and discussing the feasibility of the results and whether the information management suggestions would make an impact on the company or not.

4 Results

In this chapter, the results from the literature review, the case study, and the cross analysis of them will be presented. The following subchapters are layered with accordance to the IQ aspects presented in Table 3 in the first subchapter. The results from the literature review will serve as a base for answering research questions no. 1, and the results from the cross analysis will serve as a base for answering research question no. 2.

4.1 Literature Review

From the articles found in the literature search, a pattern could be seen over which aspects and functions that were important for IS management in general, and IS management in a New Space production environment in particular. To facilitate the analysis of the results, the findings were divided between technical IQ aspects, which answer research questions no. 1, and practical IS functions, which contributes to the answer of research question no.2. The aspects and functions are here presented in table 3 and 4, sorted based on best visual presentation of the results. In the text following the tables, the aspects and functions are discussed, where also aspects and functions that were only mentioned a few times are brought up under the subchapters *"Others…"*.

4.1.1 Theoretical IQ Aspects

Here, the theoretical aspects are presented in Table 4, followed by explanatory text.

Table 4. Information management theory – IQ aspects

Author	Accuracy	Communication & Cooperation	Timeliness	Completeness	Amount of information	Accessibility & Findability	Understandability	Consistency
Davenport & Klahr 1998	x							
Ehikioya 1999	x		x	x	x			
Yangchun 2010	x			x				
Tam et al 2010	x			x			x	
Strong et al. 1997	x		x				x	x
Chou & Hong 2013	x		x	x			x	x
Hüner et al. 2011	x		x					x
Batini et al. 2018	x		x	x				x
Marttonen-Arola & Baglee 2019	x		x		x			
Paiva et al. 2002	x	x				x		x
Beheshti et al. 2014		x						
Abadi et al. 2017		x						
Ranjan et al. 2018		x						
Karmini et al. 2007		x						
Gattiker 2007		x						
Somers & Nelson 2004		x						
Ho et al. 2004		x						
Buniyamin & Mohamad 2005		x			x	x		
Gustavsson 2008		x	x		x	x	x	
Sanchez-Rodriguez & Martinez-Lorente 2011			x					
Snider et al. 2007			x		x			
Zare & Ravasan 2014			x					x
Roetzel 2019					x			
Ben-Arieh & Pollatscheck 2002					x			
Govindaraju & Putra 2016					x	x		
Bigdeli & Rismanbaf 2009						x		
Mandal & Bagchi 2016						x		
Bevilacqua 2015							x	
Wang 1998	x		x	x	x	x	x	x
Wang & Wang 2009	x		x	x	x	x	x	x

Accuracy

Batini et al. (2018) defines accuracy as *"the closeness between a value v and v', considered as the correct representation of the real-life phenomenon that v aims to represent."* It is described as one of the fundamental information quality aspects (Ehikioya, 1999; Yangchun, 2010; Tam et al., 2010; Strong et al., 1997; Chou & Hong, 2013; Hüner et al., 2011; Paiva et al., 2002; Wang, 1998¸Wang & Wang, 2009). Martonnen-Arola & Baglee (2019) discusses IS waste, where incorrect data is mentioned as an important factor. They argue a big contributor to waste lies in inaccurate data being transmitted through the whole information process; and that data of poor quality can result in conclusions and analyses being wrongly done based on it, which can result in suboptimal decision making. One way of increasing the accuracy of information is to focus on the information flow, where good flow and thereby accurate data facilitates accurate forecasting and planning (Davenport & Klahr, 1998).

Communication & Cooperation

Communication & cooperation, alluding to the information carriers enabling the communication & cooperation within an organization, was also one highly discussed aspect. The communication enablers should support open, interdepartmental communication and cooperation, through the entire organization (Paiva et al., 2002; Beheshti et al., 2014; Ranjan et al., 2018; Karmini et al., 2007; Somers & Nelson, 2004, Ho et al., 2004). Abadi et al. (2017) identified that in a production environment that must deal quickly with unexpected events, the possibility for different system users to interact with each other was vital. Ho et al. (2004) described that by spreading and integrating the information among different departments in an organization, the quality of decision making could be improved and thereby also the overall production performance. On the opposite side of the spectrum, Buniyamin & Mohamad (2005) identified poor communication as a reason for ERP systems not working optimally, and Gustavsson (2008) discussed the balancing act of having mainly technical information carriers *versus* having organizational ways of communication, describing how *"Having high levels of technical integration but no person to person communication can lead to incorrect or incomplete information be transmitted without notice and reaction. High levels of organizational integration (e.g. regular meetings) and low levels of technical integration (e.g. emails) can provide the company with perfect but delayed information."*.

Timeliness

Timeliness, by Bailey and Pearson (1983) defined as *"the availability of the output information at a time suitable for its use"*, was also one commonly mentioned aspect of information quality (Strong et al., 1997; Chou & Hong, 2013; Hüner et al., 2011; Batini et a., 2018; Gustavsson, 2008; Sanchez-Rodriguez & Martinez-Lorente, 2011; Zare & Ravasan, 2014; Wang, 1998; Wang & Wang, 2009). Ehikioya (1999) ascribed this to the fact that the system users often have a deadline to act before, or that in a rapidly changing business environment, late or outdated information is of no value or use. Martonnen-Arola & Baglee (2019) stated that having to wait or search for information, or having information waiting to be applied to the process, is a IS waste.

Completeness

Batini et al. (2018), defined completeness as *"the extent to which data are of sufficient breadth, depth, and scope for the task at hand"*. Ehikioya (1999) agreed with the definition of completeness as "*the ability to provide all the facts of interest to its users"* and identified that the completeness of information have impact on the correctness, precision and the usability of the information. Chou & Hong (2013) showed by a confirmatory factor analysis, the importance of having complete information for manufacturing companies in the US, for meeting demands, have high effectiveness, and high efficiency. The importance of the aspect is further confirmed by Yangchun (2010), Wang (1998), and Wang & Wang (2009). Wang (1998) also emphasized the influence the point of view has on the completeness; information that one user might find complete, can be perceived as not complete at all by others.

Amount of information

The amount of information flowing through the system, as well as provided and displayed to the user, is another important information quality aspect (Ehikioya, 1996; Gustavsson, 2008; Wang, 1998; Wang & Wang, 2009). Govindaraju & Putra (2016), suggest that the information exchange should be limited to only what is essential for collaboration in order to evade information overload, Snider et al. (2007) gives examples of information that might not be necessary to provide to everyone, such as detailed information about project progress or target business objectives. Information overload, due to a too vast amount of information, is a productivity killer affecting both individual users as well as the system and the entire organization (Buniyamin & Mohamad, 2005; Roetzel, 2019; Ben-Arieh & Pollatscheck, 2002). Martonnen-Arola & Baglee (2019) describes how users being faced with unnecessary information in decision making, spends more time and resources in order to focus on the actual relevant information. Too detailed, duplicate, or non-relevant information also affect the time consumption and resource use when they, despite being of no use to anyone, are gathered, stored, analyzed and transferred in the system. To battle this, Roetzel (2019) suggests reducing the IS's complexity, reduce the amount of information in circulation, and that the users and the system should be able to filter information.

Accessibility & Findability

In line with the communication & cooperation aspect, information should be either directly accessible, or easy to find for anyone in the organization in need of it (Paiva et al., 2002; Gustavsson, 2008; Govindaraju & Putra, 2016; Wang, 1998; Wang & Wang, 2009). Bigdeli & Rismanbaf (2009) describes how easy access to information not only facilitates the use of information, but also reduces costs. Paiva et al. (2002) argues that with shorter time to find the right information, the total response time to change may decrease. Buniyamin & Mohamad (2005) gives poor visibility as a reason to information being hard to find. Mandal & Bagchi (2016), and Sanchez-Rodrigues & Matrinez-Lorente (2011) suggests having an archive for information and documents that is of no direct use, but still important to save, in order to retrieve it when required, like scrap rates, rework, cost of quality.

Understandability

Being able to understand the information provided is also mentioned as an important information quality aspect (Tam et al., 2010; Strong et al., 1997; Chou & Hong, 2013; Gustavsson, 2008; Wang 1998; Wang & Wang, 2009). Bevilacqua (2015) adds that it should also be easy to see which information that is aimed for individual functions or units in the organization, and which information that should be shared throughout the organization. This is supported by Wang (1998) who argues that the IS users must understand how the information is produced and maintained so that the communication between the roles can be as effective as possible.

Consistency

Consistency is by Batini et al. (2018) defined as *"the absence of any violation of business rules in a database. In the relational model of data, any violations of referential integrity is an example of inconsistency."*, Zare & Ravasan (2014) adds that consistency also aims to the information content and presentation, and the aspect is mentioned as important to information quality (Strong et al., 1997; Chou & Hong, 2013; Hüner et al., 2011; Batini et al., 2018; Paiva et al., 2002; Wang, 1998; Wang & Wang, 2009). Strong et al. (1997) argues further that by storing duplicate data in multiple places through the system and organization, it becomes harder to update the information regularly and the use of duplicate information could also result in different outcomes from *the same* information. Hüner et al. (2011) suggest centralized assignments of unique identifiers and having clear role and responsibility specifications for data maintenance, to avoid inconsistent, duplicate, or wrong positioning of data.

Other

Other factors that were mentioned as important aspects to consider in relation to quality of information was conciseness, credibility, and usability and value.

Concise representation of information can mitigate having too large amounts of data or inconsistent data, but the information should not, on the other hand, be too concise since the understandability and completeness then can be affected in a negative way (Gustavsson, 2008; Paiva et al., 2002; Wang, 1998). The credibility of information is also an important aspect (Gustavsson, 2008; Strong et al., 1997; Wang, 1998). Strong et al. (1997) describes how it is common for information users to accept *hard* data and information as true without second thought which can result in false information being carried through the system without notice. On the other hand, if the user doesn't trust the data, additional time and resources can be put on confirming the data which might be completely unnecessary if the information turns out to be accurate.

The information provided should also be easy to use in order for the users to be able to fully access and understand the value provided by the information (Ehikioya, 1999; Marttonen-Arola & Baglee, 2019). When the information is presented in an easy to use format, users are also more likely to use the system to its fullest and not use "home-made" information solutions (Zare & Ravasan, 2014). Bevilacqua (2015) suggests that in order to further facilitate value streams of information, focus should be put on making the information flow efficiently, particularly the most valuable and critical information.

4.1.2 Practical IS Functions

Here, the practical IS functions are presented in Table 5, followed by explanatory text.

Table 5. Information management practice – IS functions

Author	Standardization	Data transfer	Customization
Bigdeli & Rismanbaf 2009	x		
Karmini et al. 2007	x		
Ehikioya 1999	x		
Gattiker & goodhue 2004	x		
Soliman & Youssef 2003	x		
Gustavsson 2008	x		
Rondeau et al. 2006	x		
Tambo 2018	x		
Snider et al. 2007	x		
Verhagen et al. 2015	x	x	
Somers & Nelson 2004	x		x
Ho et al. 2004	x	x	x
Govindaraju & Putra 2016		x	
Paiva et al. 2002		x	
Samaranayake 2009		x	
Yee 2005		x	
Huang 2017		x	
Marttonen-Arola & Baglee 2019		x	
Bevilacqua 2015		x	
Wijaya et al. 2018		x	x
Buniyamin & Mohamad 2005			x
Strong et al. 1997			x
Upadhyay et al. 2011			x
Chou & Hong 2013			x
Zare & Ravasan 2014			x

Standardization

As a way for controlling all of above found factors [except Accessibility & Findability], standards and guidelines for input data and data management are suggested (Ehikioya, 1999; Rondeau et al., 2006; Snider et al., 2007; Somers & Nelson, 2004; Ho et al., 2004). Gustavsson (2008) adds that communication & cooperation can also be improved by having standardized communication structures. Verhagen et al. (2015) identifies the creation of non-relevant, duplicate or excessively detailed information as an IS waste, sprung from the lack of standardized information creation structures.

The consistency and completeness can be affected through official guidelines on how to produce documents preventing the occurrence of duplicate or irrelevant information, which can save time, resources, and budget (Bigdeli & Rismanbaf, 2009). Gattiker & Goodhue (2004) describes how information standards also can eliminate the need of correcting or translating inconsistent information, and thereby improving the accuracy by eliminating translation error and understandability ambiguity about how to interpret the information. Snider et al. (2007) describes formal documentation as a way of supporting the IS's rigidi and battling un-timeliness by ensuring no tasks or deadlines are missed.

Soliman & Youssef (2003) suggests using standardized ways of identifying critical information in order to battle vast information amounts, an argues that the better the quality of the information is, the faster can the organization react to fluctuations in the business environment, and thereby gain competitive advantage. The identification could be done via value stream mapping of information needs and flows, and the identification of efficient operations, information that provides control, or measures performance (Soliman & Youssef, 2003). Karmini et al. (2007) suggests that standardization could also be applied on the project management process and the information management therein, by standardizing the way of monitoring and measuring the project size, scope, progress, risks, and efforts. As for the content of the information standards, Tambo (2018) suggest that all new added data should consider information ownership, users, range and connection in the organization, quality, among others.

Data transfer

Another way of affecting the accuracy and timeliness of information is by increasing the automation by using real time data (Yee, 2005; Wijaya et al., 2018). Using real time data and information in decision making diminishes the risk of making suboptimal decisions due to the usage of false information (Ho et al., 2004), something extra important in a dynamic and fluctuating business environment (Paiva et al., 2002). Govinadaraju & Putra (2016) describes how real time documentation of process steps and real time data exchange eliminated the manual data collection which often is less precise and time consuming. Further, they go in on the composition of the IS, arguing that detailed examination of normal production flows is unnecessary, and that only deviations in production should be analyzed. Marttonen-Arola & Baglee (2019), and Verhagen et al. (2015) both advances that suggestion by arguing that only process valuable information should be collected, by describing unnecessary transferring and processing of information without any value being added, such as transforming information into required formats, copying information, hunting down information, or writing summaries and documents that no one reads, etc., as IS waste. Bevilacqua (2015) gives the suggestion to simplify all information processes in order to minimize the need for information management to avoid this, and to only deliver information when, or if, it is requested by a user. Samaranayake (2009) suggests having strong integration between cross functional processes, but to limit the manual interface between the broader process cycles. Huang (2017) suggests having feedback information regarding recourses and job progress.

Customization

As for customization of the ERP system, the opinions differ. Strong et al. (1997) and Chou & Hong (2013) mention the ability to customize the IS and the information as an IQ aspect. Ho et al. (2004) and Zare & Ravasann (2014) gives it as a tool to meet the requirements of the individual units and users and support their daily activities, which Buniyamin & Mohamad (2005) supports by identifying poor user sophistication and user needs not addressed as a reason for ERP implementation failure.

Upadhyay et al. (2011), on the other hand, argues that customization should be minimized, supported by Somers & Nelson (2004) who argues that customization is costly, the implementation time becomes longer, and the IS will no longer be compatible with maintenance schedules, upgrades, etc. Wijaya et al. (2018) takes the middle road by suggesting high IS customization, but only providing an adequate selection of applications for the users.

Other

Other IS functions that were mentioned were process visualization, system feedback, end-to-end IS implementation, and alignment of strategies.

To facilitate good communication and cooperation, and for the users to get a good understanding of the information flow and the information's utilization, the information process should be transparent (Sanchez-Rodriguez & Martinez-Lorente, 2011; Samaranayake, 2009).

To facilitate good information flow and be able to quickly and fully react to changes in the business environment, the organization should strive towards having an end-to-end IS (Karmini et al., 2007). This can be done by integrating existing information management solutions in the ERP system, for example, and have closed loop processes with tight linkages between the different manufacturing applications and their adjacent information applications (Gattiker, 2007). Coronado (2003) mentions that in a clear way aligning the information strategies with the existing business strategies can also be a good way of battling high levels of fluctuations, and become more responsive to changing customer requirements while at the same time keep a high focus on manufacturing cost effectiveness.

Ho et al. (2004), and Somers & Nelson (2004) suggest that a built-in feedback and auditing system should be used to automatically find errors in the information and get rid of subjective opinions that can occur in manual auditing. Bevilacqua (2015) suggest, whether automatic or manual, continuous reviews and improvements of the IS should take place in order to get rid of outdated information and no longer optimal system functions.

4.2 Case Study

Based on the interviews and the observations at the case company, the information needs over different roles in the company, and the information flow could be explored. The interviewees perception of the flow showed that there are big uncertainties connected with the knowledge of where information comes from in the IS, and who input information are aimed at. Following is a description of the roles and the information creation and needs connected to them. The users views of the connection between the roles and the perceived information flow is first visualized in Figure 3.

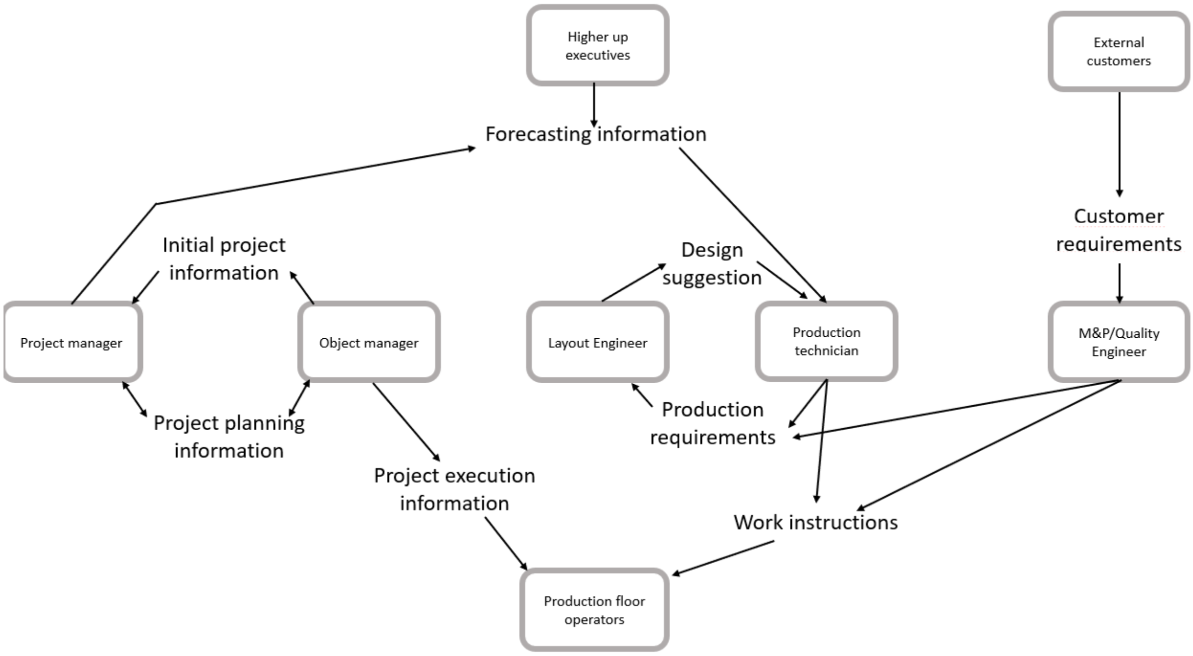

Figure 3. The information connections between the roles based on the interviewees' perceptions.

4.2.1 Interviews

Project managers are the owners of the production orders. They define, executes and closes project, along with project budget management, and communication of project status. They create the information that is used for project forecasts including times, costs etc. and information used for project planning. To mediate this information, they use various information carriers such as the ERP system, websites, documents and meetings. The information needs consist of status in production, project information others have created, technical data from the production, data that they turn into information regarding project forecasting, resource planning and offers.

Object managers works as sub-project managers, initiating orders and reserving needed material, transforming production data to information, decides what components to assemble and when, executes projects, and communicate project statuses. They create initial information to customer orders regarding deliveries, production routing, deadlines, information to production orders, when a project is initiated. The information needs consist of construction items, information from production orders, measurements from production operations for statistical compilations

M&P/Quality Engineers fills the role of technical assembly experts, creates quality documents, and communicates with stakeholders. They create information and guidelines for how to fulfill customer demands, and creates the quality documents for every product, defines product qualification plans, updates work specifications when new guidelines come from the customers, and writes quality compliance documents. The information needs consist of quality, safety, legal etc. demands from external partners, project plans and work instructions to apply the demands to, and product test data for the quality compliance documents.

Layout Engineers designs PCBs, creates bases for production- and assembly orders, and configurate and rework assembly orders. They create assembly instructions, work procedure and guidelines, product construction guidelines, and make changes if needed in above mentioned documents if a request has been made. The information needs consist of data used for product design in CAD, information for work instruction, or specific design demands.

Production technicians work with the continuous improvements in the production, by developing production methods, defining and measuring KPI: s, lead improvement initiatives, and develop new work procedures. They create initial documents, presentations, investments suggestion, used for production improvements and work instructions, production calculations, and descriptions of the production processes used both for production development, but also for production support. The information needs consist of organizational needs and strategies, development plans, and also information regarding planned manufacturing of new products and their design, elements, and process requirements.

Perceived problems

Project managers needs to make estimations when creating offers regarding duration, costs etc. based on their own experiences. It is hard to know where to find the information they need sometimes, and hard to know how much they can trust the information which results in them sometimes having to do “reality-check” to make sure the data is accurate. They are sure that they have used wrong information in the past without their knowledge. Time reporting is hard for the operators which results in the project managers needing to make time estimations.

Object managers needs to make estimations for durations in routing, and other estimations if the production personnel have not documented enough (often durations and time notions). They use own excel document to process and store information since it can provide a better compilation of times, dates etc. and the ERP system is too messy, which can result in deadlines being missed for example. The place for where to find information for the work instructions varies, possibly depending on what project manager that process that information and where they choose to submit it. When searching for documents in the ERP system, copies of the same document or at least with the same name comes up. Common notion is to just open the first document and ”ctrl-F” for the information needed.

M&P/Quality Engineers The operators are faced with too much information at the same times as there are low knowledge of how to find the right one. This often result in the users not even trying to search for the information, and instead finds someone who can tell the information, or they make estimations.

Layout Engineers perceives the ERP system as extremely unintuitive and not user-friendly which results in the knowledge about how to use the system being next to nothing for people not using the system regularly. The data used for the assembly instructions are often not complete which results in them having to make a lot of assumptions, which usually leads to rework later. They are not sure if the information they create actually is what that information customer needs.

Production technicians The operators are overflowed with information. Throughout the organization, there is low knowledge of what information that is of value, where one can find the information they need, and how to use the ERP system. Many uses their own home-made information management solutions, which isn’t accessible to other than those they have directly shared them with. When editing and saving a document, it is not always certain that it is done on the system server. Because of this, local, and different, versions of the same document exist at multiple places in the organization at ones, and it is impossible to see straight away were they can be found and which of the same documents that is the latest or the most relevant. Documents could also be saved as copies on the system server, which in the same way results in many different versions of the same document, but this time they can be found in the same place in the system. For example, when searching for a document with a specific name, the search could result in 10 results, all the same document with the same name, but with different versions of the information in them.

4.2.2 Observations

In the production, it was observed that most, if not all, of the machines can supply machine data, but that that data is only used for a few machines. The reason for this seems to be a mismatch between the data output from the machines, and the traceability of specific components. The general view is that if machine data is used straight from the machine, the traceability of the components will be lost. The machines can provide information about which components it uses and when though, which facilitates component traceability. This indicates that the traceability problem occurs when the machine data is processed in the IS. A proof of this is that for some machines, the machine data is used with success. Connected to this, in most processes where machine data was not used, it could be observed that when the cycle times for different processes are manually submitted to the system, it is possible to choose a preset cycle time. The source behind this preset value is unclear, and often has no connection to the real cycle times at all.

Regarding the document management, it could be observed that a lot of information were copied straight from one project document to another. Because of this, it is not guaranteed that all information in the new document is relevant for the new project. For example, new quality demands could have occurred since the last document were written/copied, but those are not submitted into the new document since they weren't present in the old version of the document, which make the new document lack important information. At the same time, a lot of information that were only relevant in the old document could be copied into the new, making the new document heavy with irrelevant information.

It was also observed that new information was continuously added without revision of current and old information, resulting in document containing large amounts of outdated information. The documents could also contain information that was relevant and useful to parts of the production in general, but that shouldn't be found in that particular type of document. One example of this is that quality documents not only contained information about quality requirements, criteria, limitations, etc., but sometimes also information about work procedures that were not directly connected to specific quality demands, such as the general work procedures behind spot welding for example. On the same hand, changes in information has been done over time, but has never been documented in the system.

Unrealistic data could also be found that was impossible to trace to its source, and no one seemed to know where it came from or why errored data existed in the system. The common notion was to simply accept that all information could not be trusted. The version of the ERP system that is used is also outdated since long, which makes the maintenance hard and not cost efficient.

4.3 Cross Combination

In this subchapter, the theoretical information quality aspects are compared with the results from the case study. The resulting comparisons are also compared with the suggested practical information quality functions that were found in the literature study. Table 6 shows the relation between the interviewees and which IQ aspects they thought of as important.

Table 6. The interviewees perception of problems related to the IQ aspects found in the literature study

Aspect	Object managers	Production technicians	Layout engineers	Q&O engineers	Project managers
Accuracy	x	x	x	x	x
Communication & Cooperation	x		x		
Timeliness		x			
Completeness	x		x	x	x
Amount of information	x	x		x	
Access & Findability	x	x		x	x
Understandability					
Consistency	x	x			

Accuracy

Instead of using real time data provided by machines used in production, findings showed that personnel throughout the organization often made own estimations of for example task duration and costs or using a preset value already in the system. When comparing the difference between planned production outcome versus real production outcome, for processes that used estimated data, with the few processes that use machine data, the difference was significantly higher for the estimated data processes. The successful use of machine data for some processes also showed that the problem with traceability is probably a minor, purely system-technical one.

The lack of standardized, easy to use, methods for information input, and the lack enough knowledge about how to use the ERP system also affected the accuracy of information. There are some guidelines and document templates provided, but they only contain basic information such as title, document number, etc. which makes them inexpedient for their purpose.

With Martonnen-Arola & Baglee (2019) discussion regarding IS waste in mind, above factors, and the fact that incorrect information could be found throughout the whole system just by observing it briefly, shows that a lot of time and resources probably are put on transmitting and processing errored information. As confirmed by the project managers, this information has probably been used to make suboptimal decisions without anyone’s knowledge.

Communication & Cooperation

The lack of user knowledge obstructed the open communication in the company. Since the users didn't know who the owners were for different information, direct communication regarding data or asking questions could not be done in an easy manner. The usage of own information management methods also resulting in information not being shared with everyone, information that could be relevant to other users in the company. Some information was also only brought up at meetings, and if no notes were taken and the participants didn't remember all that was said, the information would get lost. As Buniyamin & Mohamad (2005) identified, this poor communication could be one of the reasons that the ERP system wasn't thought of as successful in the company.

Timeliness

When reviewing quality documents used as supporting information in the production, quality demands were found that had expired or otherwise were no longer relevant, dating back to the oldest finding being over 10 years past expiration. Some outdated information was easily identified due to it containing dates, while other outdate information where pointed out by the interviewees who simply remembered which past update that had made the information irrelevant. Despite knowledge of outdated information in the system, no effort had been put towards cleaning up the documents. This could probably be traced back to the habit of copying information between documents, without reviewing the actual content.

Since some information were only brought up during meetings, there could be a risk that that information has gotten old by the time the meeting is held. All interviewees also described that they had to put a lot of time towards searching for information or waiting to get it from another user, which by Martonnen-Arola & Baglee (2019) is described as an IS waste.

Completeness

Like described under the accuracy aspect, the users must often make assumptions due to missing data. The reason for it missing seemed to be poor knowledge or poor motivation within the production floor operators to submit the data and information into the system. Like Ehikioya (1999) described, this lack of information that often leads to the users making their own estimations impacts the accuracy and the usability of the information. The Layout Engineers also confirmed Wang's (1998) view on completeness. Since they don't know what information the next user needs, they submit information that they think is useful and complete, but the amount of rework suggests that the information they submit is not complete to other users. The reason for the rework could also lie in the Layout engineers not being provided with complete information themselves, resulting in them making design decisions for example, that later turns out to not work.

The copying of documents also affects the completeness. It was observed that when copying whole document contents to create a new one, there was no guarantee that the old information would be complete also in the new context. This resulted in a lot of documents being very heavy with information, but at the same time lack all the information needed.

Amount of information

Like just described, the copying of document resulted in documents being more and more hefty every time a new one was created. It was also observed that some documents not only contained the, for it, relevant information, but also information that should be found in other parts of the system instead. The interviewees described that this affect the production floor operators the most, which in line with several authors in the literature review describing information overload as a productivity killer, might be *extra* bad since they are the ones who does the most value adding work in the organization, and therefore should be provided with optimal conditions to perform their work. The large amount of information also confirms that a lot of time and resources probably are put on transmitting errored or unnecessary information, as described in above mentioned factors. Confirmed in the interviews, a lot of time is also put on finding the right information, time and effort that could be put on value adding or supporting activities instead.

Accessibility & Findability

Connected to the communication & cooperation in the organization foremost, it can be hard for the users to find the information they need when searching for it. This was seen be partly due to poor knowledge of where to find information, poor strategies of information input, and technical problems in the system. The poor strategies of information input were described by the object managers who sometimes found the information they needed in one part of the system, sometimes not, which they though depended on who made the information input and their personal preference of where to put the information. The technical problem was that when submitting a new document into the system, the new document could be stored as a copy, parallel with all previous copies of the same document. The document was easy to find, but then it was hard to know which of the copies that was the most relevant. In line with Paiva et al.'s (2002) discussion, this poor accessibility and findability could be one contributing reason to the response times to change, and the overall lead times being so long.

Understandability

The understandability of the information was not brought up during the interviews and was neither seen as a problem during the observations. The understandability of how the ERP system works on the other hand was mentioned by all interviewees, which resulted in problems relating to all other aspects mentioned in this chapter.

Consistency

The lack of standardized information input procedures resulted in low information consistency throughout the system, and the lack of knowledge resulted in personnel partly not knowing where the information they were using were coming from, and partly resulting in them using their own home-made methods for information management, including everything from using Microsoft Excel and other support software programs for tasks that could be done directly in the ERP system, to using post-it notes put on the wall behind the computer. This affects all above-mentioned aspects. With no consistency for information input, it could be observed that unnecessary information often were put into the documents, the information became hard to find since there was no consistent way of where to submit information, and the inconsistency in document storage in the system resulted in duplicate information existing at the same time. As Strong et al. (1997) described, and the interviews and observations confirmed, this made it harder to update the information regularly, where updates could result in different versions of the same document existing locally in different places in the IS.

Others

A problem the project managers emphasized was that they could never be sure of the credibility of the information, which resulted in them having to do “reality checks” regularly. This confirms Strong et al.’s (1997) view that a lot of additional time and resources are spent unnecessary if the information turns out to be true. The interviews also confirmed the opposite, that it is very easy for errored information being transmitted through the system without anyone knowing. Strong et al. also described this as it being common to simply accept data and information as true when it is presented in a *hard* and straight forward way. If the project managers are the only ones questioning the information, and they often find faulty information, it is easy to believe that lots of errored information goes by without notion.

The home-made solutions described under the consistency aspect could also be connected to the systems and the information’s usability. Zare & Ravasan’s (2014) idea of low usability resulting in poor system usage and more home-made information solutions being used was confirmed in the observations and interviews. Many of the interviewees was not happy to use their own solutions but did it because they felt they had to in order to not miss any important information.

5 Discussion

In following chapters, the results from the literature study, the case study, and the cross analysis, and what implications they can have on the case company will be discussed. Further, the execution of the research will be discussed along with ethical and sustainability aspects connected to the results and execution. Finally, it will also be discussed what the results are unable to tell us, and what future research that should build on this research.

5.1 Results

The aim of the thesis was to contribute to the theory of how information should be managed in a production environment that used to involve low volume production done to a highly manual degree, towards a production environment that meets the demands of New Space production, and to answer the research questions regarding what IS functions and information aspects that are needed to fulfill the requirements on New Space production, and how they can be implemented at a company.

The results from the literature review showed that for a production company needing to fulfill the production demands New Space production entails, being lower costs, lower lead times, higher volumes, and higher flexibility, it is important to focus on the information quality aspects Accuracy, Communication & Cooperation, Timeliness, Completeness, Amount of information, Accessibility & Findability, Understandability, and Consistency. The literature review also provided links between these theoretical information quality aspects, and the three identified IS functions, standardization, data transfer, and somewhat system customization, for all the aspects except Accessibility & Findability.

5.1.1 Cross analysis links and connection to New Space

The findings from the literature study were compared with the finding of the case study. This cross analysis showed that for a company in the situation this research investigates, the IQ aspects found in this research were indeed important. The case study could also provide additional links between the theoretical information quality aspects and the practical IS functions. Figure 4a shows the links between the theoretical aspects and the practical functions the literature provided, and Figure 4b shows the additional links provided by the case study results.

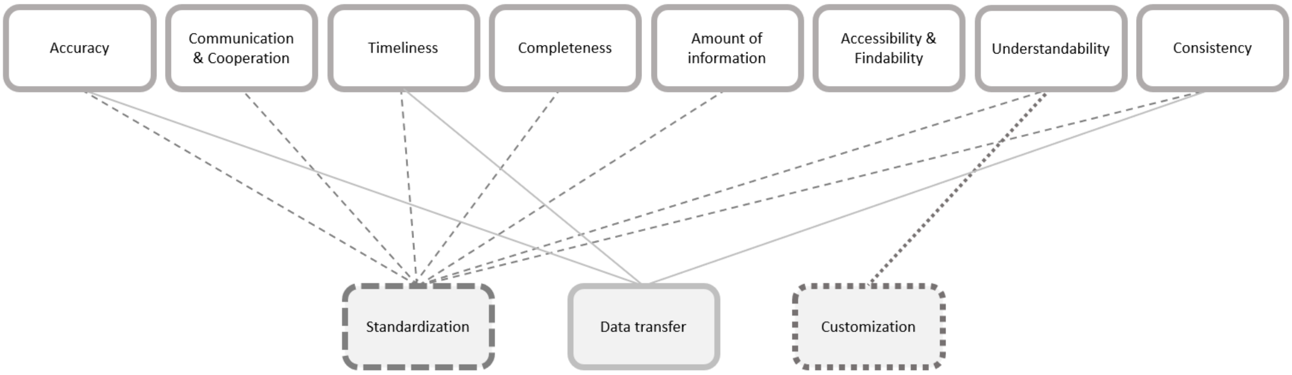

Figure 4a. Links provided by the literature

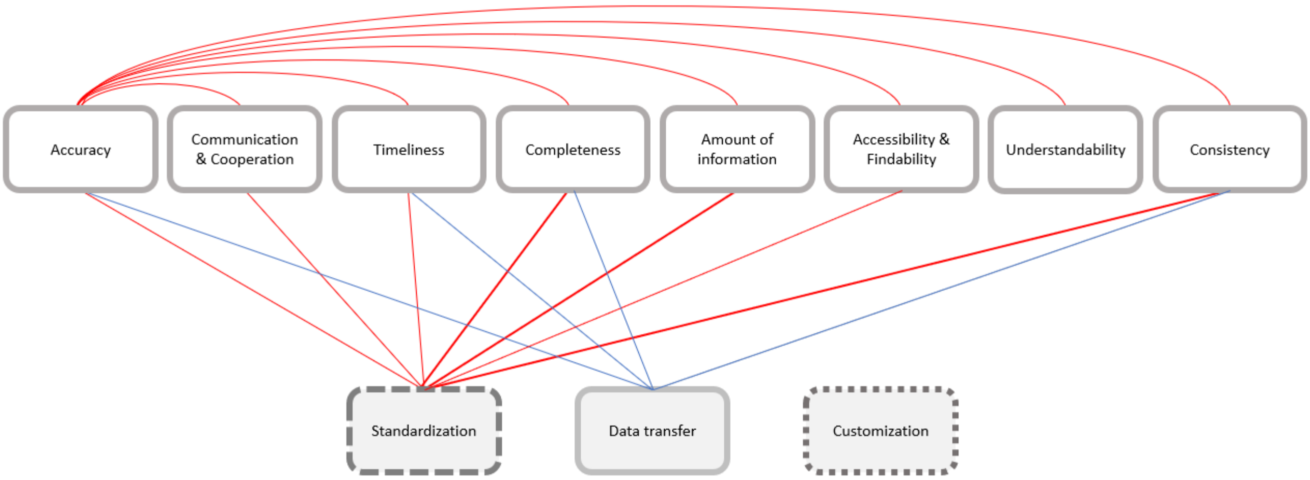

Figure 4b. Additional link found or confirmed by the case study

The cross analysis indicated that standardization could impact the accuracy of the information in the company by providing standardized ways on information input to the system. The impact would probably be of secondary cause, where standardization firsthand would impact the communication & cooperation, timeliness, completeness, amount of information, accessibility & findability, understandability, and the consistency, and all these factors would together impact the accuracy. The accuracy of information was found important since bad information and data can result in suboptimal decisions, bad for the companies competitiveness, forecasting and planning not being realistic enough which will impact the company's responsiveness to changing customer demands, and that more time and resources will be put on rework or on finding the right information which can have high impact on the overall costs and the lead times.

As for communication & cooperation, and also accessibility & Findability, if standardized communication guidelines were to be created, it could handle what information should be shared in which way, so that similar information always can be found in the same place. In the mapping over the users' perception of the information flow, visualized in Figure 3, the limited connections shows that the information flow is unclear to the users, since more connections otherwise would have been provided. How information was documented and fed to the system turned out to be dependent on the individuals understanding of the system, and the understanding was shown to vary through the organization. From the literature study, Abadi et al. (2017) showed that good interaction is important for dealing with fluctuating production environments, and by the same reasoning as for accuracy, when the communication & cooperation isn't working properly, more time will probably be put on searching for information which will impact costs and lead times.

Standardization could also make sure no information get lost by only being brought up at meetings for example, which could also impact the timeliness by making sure *meeting-information* doesn't reach its user too late. The timeliness could further be impacted by having standardized reviewing processes, where information in the system and in documents are reviewed continuously to make sure that all old information is removed or stored in another, appropriate place. Having outdated information or having to wait for information would again impact the cost and lead time because extra time must be put on searching for information, additional time that doesn't exist in a rapidly changing business environment

The completeness would be impacted by making sure that all information the users need are provided to them and that one user doesn't have to guess what information the next user needs. This could also help battle the large amounts of unnecessary information, by getting rid of all information not vital. A standardized way of creating new documents and for which information that can be copied between documents would also probably be beneficial, by making sure that the same information doesn't exists everywhere and nowhere at the same time, or that outdated or errored information keeps getting transmitted. Again, incomplete or too much information results in the users having to search for information, or that they make their own assumptions that affects the accuracy of the information. Since standardization is all about consistency, that factor would of course be impacted also by making sure the same information is put into the system in the same place regardless of who does it.

All of this would rely though on the personnel following the standardized input guide, and not do any own estimations or use the preset values in the system. If the standardized information management ways were to be followed, all of these would together impact the accuracy, and each other. By this, standardization could lead to time, resources and budget being saved, which affect the overall production costs, the lead time, and the flexibility and responsiveness of the system.

The cross analysis also confirmed the connection between real time data transfer and accuracy, by showing that where machine data were used, forecasts and production information became much more reliable. In a previous project, Bärring et al. (2018) showed that automatic data transfer could solve a lot of problems in the case company. This was since there were a lot of estimations being done throughout the organization partly because the production floor operators didn't or wasn't able to submit the right production data or any data at all into the system. This problem would completely be eradicated if direct machine data would be used, making more time available for the production floor operators to focus on value adding work, and making estimations not required for other personnel through the company. By improving the transfer of data and information, the risk of using inaccurate data diminishes, which was shown above to affect the flexibility and responsiveness of the company.

One factor that wasn't touched upon in the case study was the understandability of information. This could either be because of all interviewees understanding all information provided to them, but more plausible would probably be that they have not reflected over the understandability of the information. The understandability of the ERP system was on the other hand seen as a big problem. This seemed to impact all information quality aspects greatly, since the inability to use the system properly was one big reason for data not being submitted into it, peoples using their own home-made information solutions, estimations having to be made, and important information possibly being missed because the system provided several copies of the same document when doing a search. Speculating, the fact the system version that is used in the organization is outdated is probably not helping encouraging people to learn the system either.

Except the lateral link between understandability and communication & cooperation, the literature provided one link to understandability, being system customization. Customization could probably help the individual users by providing them with the right tools that they need, but if the system were to be completely customized based on every user's individual need, it would be probably be very costly. Since maintenance of the system already is hard due to it being old, customization would aggravate that problem. What could impact the customizability though is how it would be done. If the whole system software were to be change every time a new customization was to be made, the process would be costly and tiresome, but if the system is modularized, there is no need to customize already existing software. How the IS is constructed would have to be studied before drawing any conclusions about if customization is the right thing to do or not in order to raise flexibility in the system, and lower production costs.

5.1.2 Suggestions for the Case Company

Based on the discussion above, some concrete suggestions for the company are presented here for how they can improve the found information quality aspects in their IS, and by doing so become more flexible, lower their overall costs, and decrease the lead times. They are sorted by relevancy, where the first suggestion would make the most impact on the company.

- If the ERP system that is being used right now will be continued to be used, everyone in the company should get a thorough education on it in order to utilize the ERP system to its fullest.
- Real time data and machine data is already used on some processes in the production with great success. Study those processes and see how they can be implemented on all other automated processes. This will result in the production floor operators being able to focus on their value adding work instead, and that information errors will be eradicated since no estimations has to be made.
- The documents that are submitted to the ERP system or other parts of the IS and that are used by several persons in the company should be standardized, so that quality documents only include quality subjects, work instructions only include the work steps and how to perform them, etc. The content of the documents should also be standardized so that the information in the same types of documents are consistent, so

that the user doesn't have to scan the whole document every time they look for one type of information.

- The submission of document and information into the IS should also be standardized so that only one copy exists globally in the system, instead of many local copies of the same document, or that the location of information varies depending on who made the input.
- If machine data can't be used, for example when the processes are completely manual, at least get rid of the function that provide preset values since they seem to more often be wrong than right and teach everyone in the organization the importance of having the right data in order for the company to function optimally.
- Investigate if the home-made information solutions can be integrated into the ERP system via modules, this will allow the users to keep use their preferred tools, without affecting the ERP system negatively.
- Make the IS more transparent. This will provide better understanding of how the information flows, who creates and owns the information, and who to talk to it a problem arises.
- On the same line, improve the information flow, for example via information value stream mapping, in order to investigate if the flow is optimal, which in turn will e.g. affect the accuracy in forecasting and planning. When doing this, also make sure to align the information strategies there is with the business strategies, which is suggested to be a good way of battling high levels of fluctuations in production, and become more responsive to rapidly changing customer requirements while still keeping the focus on the cost effectiveness and service quality.

5.1.3 Validation Aspects

The connection between the New Space production requirements and the theoretical results was validated through triangulation by confirming the findings from the literature study with the case study and analyzing them both quantitatively and qualitatively. One factor that could not be validated was information understandability, since only one link was provided between system customization and understandability, and the area wasn't touched upon in the case study. The importance of the aspects in a New Space production environment, and the relevancy and feasibility of the resulting implications was validated via member checking.

In the member checking, it was confirmed that education on the ERP system and standardization of the IS management, data input, document handling etc. would probably greatly improve the organization. One problem that was discussed here was that a lot of knowledge about for example how different documents are written or the approach for handling different information processes are knowledge that are hidden in a few people in the organization, i.e. only they know how to perform these tasks and when they teach someone new, they teach their perception on how the tasks should be performed which is not guaranteed to be the most optimal way. This further motivates standardization, so that the problems enlightened in this thesis could be solved, but also so that no knowledge would get lost if the knowledgeable people would leave the organization.

Regarding the usage of machine data, it was found that it such data could be used, it would probably improve the error rates significantly by mitigating the need for estimations. One problem that was brought up here though was that since so many processes are entirely manual or manual with the help of not-communicating tools, the manual data input would still exist. This could be solved by higher levels of automation, where tools are used that can feed machine data directly to the system. If the organization doesn't want to invest in new machines, the suggestion of getting rid of the preset values was though of as a good idea.

5.2 Execution

Since the area of IS management is multidisciplinary, it is hard to tell how representative and including the literature review actually was. The fact that for every screening iteration in the beginning of the literature review, the majority of the articles were not included, could point at the inclusions criteria not being too delimiting. This was good since the thought behind the literature study methodology was to find as many possibly relevant articles as possible in order to not miss any important information. If the keywords would have been too restricting, most of the articles would possibly have been kept in every step instead, which could indicate that relevant articles could be missed.

The area of information quality theory is old which could mean that there are sources that were not included since they are not published online, there could also be sources only visible on other sites than Scopus. Because of the ambiguity about the meaning and the implementation of IS and information quality, there could also be sources that were not covered since they contained other terminology and keywords than those covered in this search. To mitigate the impact this could have, following the reasoning of (Brocke et a., 2009), the methodology and inclusion criteria was tried to be made as transparent as possible so that the reader of this report can themselves be able to assess the exhaustiveness and relevance of this project, and if wanting to be able to replicate the steps that this project took. The risk of missing sources because they were too old were not deemed as to risky either, since the area of IS management is highly dependent on the technology that exists, and the IS and production technology have advanced greatly over the last couple of decades.

Regarding the case study, since only one company was studied, it is hard to know if the findings from the case study are representative for other companies in similar situation, or if the findings are only relevant to companies in almost the exact same situation. Since similar findings can be found in research done on other business areas, the findings in this research is probably general enough to be applied to most companies in approximately the same situation as the case company in this research.

Compared to the literature study, the case study did not follow any specific steps in its conduction, which could have resulted in the researcher focusing on what they tough important and interesting, thus making the following results biased. To mitigate this, the researcher made sure to be aware of their own view of all the areas being covered, trying to be as objective as possible.

5.3 Ethics and Sustainability

Since this thesis have revealed structural issues and problems with RUAG's organization, the interview method gained importance. The interviewees have been held anonymous to protect them from criticism of their interview answers, they were not forced to participate in the interviews, and they were able to end the interview or not answers questions if they had wanted to. The guiding questions were also created to be as open and including as possible in order to get an as objective view as possible.

With the suggested information management processes in this project, rework, loss of resources and time, and high costs that results from bad information management could hopefully be mitigated, and it could also hinder the organization and the people in it from doing the same mistakes over and over again. This could be resulted in a better economical sustainability for RUAG, and the reduction of rework could mitigate the unnecessary use of limited resources which would improve the environmental sustainability. The solutions suggested could also ease the stress users get from having to but a lot of effort on searching, making assumptions, and reworking, which would be positive for the social sustainability in the organization.

5.4 Future Research

Future research could focus on the data collection and standardization questions related to IS in a New Space production environment, to investigate what specific kinds of information that is necessary to fulfill the information quality aspects found in this research. Since the quality of information is not only dependent on the aspects found here, but also on the company setting they exist in, a framework or guidelines for the company to use for standardizing and collecting data could be useful

It would also be useful to validate the findings in this thesis by implement them in the company and measuring the results, or by applying them to similar environments. This could either confirm that the results and conclusions in this research is accurate and reliable, or it could show flaws in this research which would provide more ground for future research.

Research could also be conducted regarding the consistency between the aspects and the New Space production requirements, to statistically find which of the aspects that are more important to focus on in relation to cost effectiveness, lead times, production flexibility, and responsiveness of the organization.

6 Conclusion

The aim of this project was to contribute to the theory of how information should be managed in a production environment that has to meet the requirements of New Space production. Those requirements were lower overall costs, lower lead times, higher production flexibility, and higher responsiveness in the organization.

To fulfill the aim, the project seeked to answer two research questions:

RQ1: What information functions and aspects are needed to fulfill the requirements of New Space production?

RQ2: How can an information management system in a company standing before this transformation be adapted to support the transition towards New Space production?

To answer research question no. 1, the results showed that the information aspects important to consider are Accuracy, Communication & Cooperation, Timeliness, Completeness, Amount of Information, Accessibility & Findability, and Consistency. Understandability was also mentioned by the literature as an important aspect, but this could not be confirmed in the case study, something further studies could enlighten. The functions that can facilitates these aspects were found to be standardization, data transfer and customization.

To answer research question no. 2, the results showed that standardization of information management really was a big contributor to fulfilling the New Space production requirements. Real time data transfer, the usage of machine data instead of manual data management and by this reaching a higher level of automatization in the production was also found to have a positive impact. Customization was also suggested to be beneficial if it was done through integration and modularization, but that factor would need to be investigated further before any general conclusions can be drawn.

If a company in the transition towards New Space production were to consider this research when improving their IS, there is a high possibility that they will lower their costs, lower their lead times, and increase their production flexibility and responsiveness towards the rapidly changing business environment the New Space sector entails. With their extensive knowledge of Old Space production, they already have a technical advantage, so all needed now are a wiliness to change, and courage enough to take on the higher risks that this to them new kind of production brings.

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