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Exploring the challenges with applying tracking and tracing technology in the dairy industry

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Abstract: The purpose of this research is to identify the various challenges encountered when using tracking and tracing technology in the dairy industry. Based on a systematic literature review, the challenges are reviewed from the supply chain perspective. The findings are then discussed within the context of a large dairy manufacturer that implemented RFID within its supply chain. The paper distinguishes between three different types of challenges regarding tracking and tracing technology: *strategic*, *technical* and *convenience* challenges, and are further categorized as either adoption barriers or implementation barriers. This study also finds that the technical requirements for implementing tracking and tracing technology pose the least difficulty, while organisational change and cyber-security risks are more critical.

Keywords: RFID and ubiquitous manufacturing, logistics in manufacturing, intelligent manufacturing systems, manufacturing plant control

1. INTRODUCTION

Recent trends in technology development offers much promise for addressing the several challenges facing manufacturers in today's dynamic business environment. To cope effectively with ever-changing customer requirements, managers are looking into technology solutions, such as tracking and tracing technologies, to improve planning and control and performance (Kache and Seuring. 2017). This increased productivity will have a significant implication for successful operations management on a factory level but also across entire supply chains (Kehoe & Boughton, 2001). More importantly, it will result in an improved service level and customer satisfaction. This is crucial in such a competitive market as it "increases the customer's confidence, strengthens the brand integrity and increases the customer loyalty" (Costa, 2013).

In the last two decades, tracing and tracking technologies have gained attention as potential enablers for improved supply chain integration, planning and control, and therefore better overall supply chain surplus (Strandhagen et al, 2016; Oluyisola et al, 2018). This has spurred research to increase the understanding of the conditions that facilitate the digitalisation of supply-chains and production systems in the recent times. It is also valuable to understand the role of digitalization in performance improvement and in raising the awareness of the risks, challenges and threats for the companies faced with digitalisation. For instance, there is a growth in available information collected from technologies like tracking and tracing systems and customer collected data. Such data has the potential to create several opportunities like improving forecasts and basing production plans on more accurate customer demand.

Kache and Seuring (2017) noted how the research on the consequences of the lack of updated and "right" supply chain information is limited. Moreover, the need to integrate with existing systems and questions about whether to tag at item level or at package level remains challenging (Kache & Seuring, 2017). Perhaps, this is one reason why adoption has been most prominent in some segments of the retail industry where finished goods items are sold mostly piece-by-piece. Within the factory, adoption is even more limited if judged by the dearth of empirical data in the literature. Therefore, there is a need to shed more light onto the challenges facing the adoption and use of tracking and tracing technologies in other industrial settings, if the potential benefits are to be fully actualised. The paper aims to fill this research gap through a case study of a large producer, and more specifically addressing the manufacturer's perspective.

1.1 Research objective, questions and scope

The paper will investigate the existing challenges and barriers for applying tracking and tracing technology in a cold supply chain in dairy producer operations. These tracking and tracing solutions suited in the dairy industry are intended to improve the accuracy and the efficiency of the planning and control in a complex supply chain whose objective is to remain competitive within the paradigm shift which is currently moving towards a more digital world, frequently referred to as Industry 4.0.

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Operational decisions-making is particularly difficult in the dairy industry as they need to address several uncertainties such as high perishability, a large variation in lead times, short delivery times, seasonality and both varying raw material availability and demand. With these characteristics this industry can be considered as one of the most complex and challenging supply chains. There is a plethora of information available supporting the statement that tracking and tracing technology is an enabler of supply chain visibility which can enable more informed planning and control. The purpose of this paper is to increase awareness of the potential challenges that may arise from these technologies.

There is an increasing importance and expectation of monitoring food in the food industry, due to reasons related to both quality and safety. The food industry is exposed to a myriad of devices, sensors and instruments that continuously analyse, monitor and control parameters such as temperature, bacterial levels, pH-levels and contamination levels. These technologies are frequently found on the factory site and it can be less challenging to control these aspects that occur inhouse. Usually, the factory has a clear understanding of these characteristics. Once the consumable products leave the factory premises it will be more difficult to monitor and control. Nonetheless, the products are a lot more vulnerable as they are exposed to more radical and unpredictable changes in the external environments which can have a major influence on the quality of the product. Simultaneously, the products will be impacted by issues related to operations and logistics. Consequently, researching tracking and tracing technologies instead of other possible technologies is very attractive for this industry as they would be able to control and provide the supply chain with information on the current status and performance of the process.

2. RESEARCH DESIGN

A systematic literature review has been carried out in Emerald Insight and Science Direct, and the articles were to be dated no later than between 1998-2018. A further condition was that the articles found in Emerald Insight should come from leading journals as this would increase the validity of the project. Science Direct had articles coming from different journals than Emerald Insight and many of these journals were not regarded as leading. Nonetheless, the contents appeared relevant and therefore the criteria for the background of the journals did no longer apply.

The pool of selected keywords were based on a preliminary search. A boolean advanced search was generated separately for both Emeral Insight and Science Direct because each database had different constraints in their search engines. The first boolean search in Emeral Insight involved three blocks and “anywhere”, however this resulted in 48 567. After several modifications such as changing the combinations of keywords and extending the search to four blocks resulted in 67 hits after having applied the constraints mentioned above. The same process was repeated for Science Direct, however here two blocks were appropriate for searching in the body of the article and three blocks were tailored towards keywords to be found in the title, abstract or list of keywords. This resulted in 42 articles. The keywords used to retrieve relevant papers were the following: planning, control, forecasting, food industry, make to stock, RFID, traceability, tracking technology, Industry 4.0, challenges and constraints. These words were combined slightly differetly across the various levels in the two databases.

In addition to the literature study, a semi-structured interview was carried out with the Logistics Project Manager at the case company. The purpose of the case study is to complement findings from the literature study, deemed necessary because of the limited studies on these challenges – from a manufacturer’s perspective.

3. LITERATURE STUDY

3.1 Findings from literature study

Initially, the literature review resulted in 67 articles from Emerald Insight and 42 articles from Science Direct. Reading through the titles and the abstracts and assessing their relevance reduced this number to 30 articles and 6 articles, respectively. After thoroughly reading through all the 36 articles, the final selection was filtered down to 33. The inclusion and exclusion criteria were based on papers having to include either food industry or cold supply chains, and it was imperative that the papers addressed tracking and tracing technology with the respective challenges. These 33 papers provided relevant information on existing technologies and the challenges when implemeting tracking and tracing technology in the cold supply chain, summarized in table 1, and the following sections will address these findings more specifically.

3.2 Existing technologies

Different traceability systems will have different capabilities and functions, some span across the entire chain, from farmer to retailer, while other solutions are bounded to one specific area. The level of information detail these technologies capture will vary. The following technologies were found during the literature study and were considered as being popular for tracking and tracing.

3.2.1 Barcodes

Barcodes and barcode scanners are a well-established technology for identifying products and they will only identify product types instead of unique items. Barcode technology can often be considered as a simpler form for tracing, nonetheless this is often preferred in industry as it is easier to implement, and it is a cheaper solution while still capturing data to the level of detail and accuracy which is required.

3.2.2 RFID

Radio frequency identification (RFID) technology is a compact technology which consists of two components: an antenna and the chip which contains the electronic product code. Real-time information can be traced continuously throughout the entire chain. With the emergence of RFID

technology, research has proven that the handling of inventory and inventory management has improved (Lao et al., 2012), especially in the food industry, as it provides real-time inventory data and hence gives a clearer visibility of stock levels. Adopting RFID technology will also lead to a reduction in human errors originally caused by manual data input. The significant benefits will be particularly experienced by the distributor and the retailer.

3.2.3 Intelligent packaging systems and TTIs

These packaging systems equipped with time-temperature indicators (TTI's) can sense the environment and based on stimuli can detect, sense, record, trace and communicate. These functions assist decision making regarding shelf life, quality, they are capable of warning when deviations occur, and they will support material and information flow (Yam et al., 2005, p.2).

Table 1. RFID challenges from the literature.

Challenges	References
Strategic challenges	
Cost of implementing	Juan Ding et al. (2014); Kumari et al. (2015); Thiesse & Buckel (2015); Li et al. (2017)
Low awareness of benefits	Auramo et al. (2002)
Information sharing	Aramyan et al. (2007); Nakandala et al. (2017); Chaudhurri (2018) ; Morgan et al. (2018)
Coordination, collaboration and trust	Robson & Rawnsley (2001); Aramyan et al. (2007); Matopoulos (2007); Juan Ding et al. (2014); Anastasiadis & Poole (2015); Soosay & Hyland (2015); Jie & Gengatheran (2018); Morgan et al. (2018)
Entrenched business practices	Faisal (2015)
Technical challenges	
Collisions	Kumari et al. (2015)
Environmental interference	Kumari et al. (2015)
Suboptimal reading	Thiesse & Buckel (2015); Kumari et al. (2015)
Data collection	Zhong et al. (2017); Kumari et al. (2015) ; Chaudhurri (2018)
Convenience challenges	
Waste and recycling of RFID tags	Chaudhurri (2018)
Lack of professional skills	Faisal (2015); Chaudhurri (2018)
Security and privacy	Kumari et al. (2015); Li et al. (2017); Chaudhurri (2018)
Regulations and standards	Kumari et al. (2015); Nakandala et al. (2017); Stranieri & Banterle (2017)
Data uniformity and standardisation	Chaudhurri (2018)

3.3 Challenges with tracking and tracing technology

The challenges with tracking and tracing technology encountered during the literature study can be categorised as strategic challenges, technical challenges and convenience challenges (Vermesan & Friess, 2014) and each of these three challenges have various aspects that will now be discussed in more detail.

3.3.1 Strategic challenges

Cost of implementing. High deployment costs remain one of the greatest constraints to applying certain tracking and tracing technology, like RFID. However, it is believed that cost will become a less significant barrier with the expected advances in semiconductor fabrication techniques required to produce some of the components. If this proves to be correct, technologies such as RFID may become a more competitive choice in the future (Kumari et al., 2015).

*Low awareness of benefits and lack of incentive*s. It is believed that there is a lack of incentives for adopting the technologies. There is also a risk in believing in additional benefits when applying new technology to old processes. These can be incompatible with each other and can lead to increased costs and inefficiency.

Information sharing. Information sharing, hence increased transparency and supply chain integration can have a significant positive impact on the entire supply chain by improving planning, production and delivery performance (Zhou, 2007). The quality and the availability of the information shared is critical and will be influenced by accuracy, timeliness, credibility, uncertainties and inter-organizational relationships. Before investing in transparency, there should be an analysis on which situations would benefit from it and where transparency would not be worthwhile (Morgan et al., 2018). With the rise of big data, it will be necessary to ensure that the masses of data are made interpretable and timely for all the partners (Morgan et al., 2018). Information sharing is not achieved appropriately in cold supply chains because temperatures are recorded but are not transmitted. When temperature data is collected it is only used at the destination to determine whether the freight is accepted (White & Cheong, 2012).

Coordination, collaboration and trust. A major incentive for coordination and collaboration is the opportunity of having access to more competencies (Anastasiadis & Poole, 2015). A supply chain can potentially comprise of several partners and there is always a risk of diverging and misaligned interests which can affect the quality of the information which is shared. The strategic value of some information can inhibit the free exchange of information (Aramyan et al., 2007). There is a tendency of associating the act of information sharing with the loss of power and dependency (Soosay & Hyland, 2015). This will be counterproductive when working towards building trust and this can be detrimental to the supply chain's efficiency (Feldmann & Müller, 2003). As a result, trust can easily be an obstruction and will limit both the depth and the width of the collaboration.

Entrenched business practices. Managers can be reluctant to change and commitment and not having all the key participants on board can lead to the technology not being implemented at all. Reasons can be due to high one-off investments.

3.3.2 Technical challenges

Collisions. A risk with technology requiring tags is the possibility of several tags being energised simultaneously when they receive the reader's signal. As a result, the various tags will transmit their response to the reader. The signals may superimpose which will then lead to a collision between the signals and will influence the data quality.

Environmental interference. Environmental factors and high-water-contents materials affect the performance of the tracing technologies (Kumari et al., 2015). These features are critical in food supply chains where foods are often characterised by possessing high contents of water, are exposed to extreme temperatures and have dielectric properties that can interfere with the signals.

Suboptimal reading. A misconception is that technology allows for an error-free detection of products. Faulty readings will directly impact the quality of the collected data (Ruiz-Garcia & Lunadei, 2011) and will for example affect the inventory control as there will be a discrepancy between the reality and the collected data (Thiesse & Buckel, 2015). A further factor that must be considered which is especially relevant in the food industry is that tracking and tracing technology usually traces and monitors the packaging that the food is contained in rather than the product itself. Therefore, there isn't necessarily a one-to-one correlation between the parameters measured on the packaging of the product and the actual parameters of the product itself.

Data collection. Not having an approachable data collection method will confine the data-based analytics and will directly impact the quality of the information and lead to unreasonable assumptions and decision making (Zhong et al., 2017). A reason for this is that the industry is lagging compared to the research which has been done on the digitalisation of supply chains. The reality is that manual and paper-based operations are still common practices, the collected data is unstructured, and the masses of data which are generated are difficult to handle as the current collection systems are limited and unable to cope with large quantities of data.

3.4.1 Convenience challenges

Waste and recycling. Ruiz-Garcia and Lunadei (2011) express that a setback with choosing certain tracing technologies concerns the handling of the end of life of the technology. A disadvantage of RFID is the recycling of the tags.

Lack of professional skills. Lack of professional skills, potentially due to insufficient or poor training of the employees in using the tracking and tracing technology, limits its potential in the supply chain (Ruiz-Garcia & Lunadei, 2011). Human error can lead to inaccurate data collection and poor data interpretation leads to poor decision making.

Privacy and Security. Privacy issues restrain the companies from taking advantage of the opportunities with tracing technologies. Consequences are counterfeited barcodes, hacking, industrial espionage, unwanted customer tracking, virus attacks and malicious intentions.

Regulations and standards. With growing transparency, there is an increasing need for regulations and traceability standards, and several standards currently coexist (Kumari et al., 2015). The lack of standards will lead to system incompatibilities making it more complicated to share information.

Data uniformity and standardisation. The process of collecting and transferring data varies between supply chain partners. This disparity makes it harder to collaborate and leads to a greater incompatibility

4. INSIGHT FROM A CASE STUDY

4.1 Brief description from case

The case company is a large Norwegian dairy product cooperative which offers a wide range of products. The products are primarily sold through all grocery retail stores, local convenience stores and kiosks. Domestically, the company face little to no competition. The company is successful internationally as well. The company makes to stock and has two different types of supply chains: direct distribution to retailers and distribution through wholesalers. The market requirements are frequent deliveries with very short response times. This is partially due to the high perishability of many of the products. The demand uncertainty is increasing because there is a large variation in periodic demand, the promotional activity is high and increasing, and the presence of the bullwhip effect is high. Despite the high perishability, the demand is still met from the finished goods inventory. The supply chain can be considered as one of the most challenging and complex supply chains in Norway. The challenges are increasing as there are more product variants and more demand uncertainty. The consequence is an even lower predictability.

4.2 The challenges from the manufacturer's perspective

Some of the points within each category of challenges will be relevant for certain specific technologies, whereas others will be applicable to a greater variety of tracking and tracing technologies. The case company experiences that their greatest challenge is strategic and weight this as the most decisive aspect when it comes to concluding whether they should implement RFID in their manufacturing. It is stressed that cost and low awareness of benefits are the primary deciding factors for adopting the technology.

From the case interview, it was expressed that the wholesaler would benefit from greater advantages when using tracking and tracing technology than the manufacturer. However, it would be the manufacturer that would have to take the costs. Prater and Frazier (2005) created a framework explaining the different barriers in applying technology and they distinguished between adoption barriers and implementations barriers from a management perspective. For the purpose of this study the definitions have been slightly modified but the

essence remains. Adoption barriers are defined as barriers that arise due to the lack of incentives and motivation, whereas implementation barriers are defined as barriers that impact the feasibility of implementing the technology in practice.

It can be concluded that in the case of using RFID technology, the adoption barriers are greater and are more significant than the implementation barriers. Physically implementing RFID is not complicated as many companies have achieved it successfully, however the greatest hinderances arise due to the failure of achieving promised benefits at high deployment costs.

4.3 Impact of the challenges on the manufacturer's performance

It is important to understand how the challenges discussed so far will influence the manufacturer's overall operational performance if they are not managed adequately. Strategic challenges and technical challenges will have a direct implication on the manufacturer's performance and abilities to plan and execute their production. Certain aspects of convenience challenges, such as lack of professional skills, can also influence the performance.

4.3.1 Impacts due to strategic challenges

The ability to share information amongst supply chain partners and the ability to successfully coordinate and collaborate will have direct consequences on the overall operational performance such as longer lead times, higher costs throughout the supply chain and inaccurate information sharing. A possible reason that strategic challenges are weighted as more important by the case copmpany may be because the implications were more immediate during the pilot project.

4.3.2 Impacts due to technical challenges

Essentially, technical challenges can imply poor data quality. Poor data quality means that incorrect data is used for decision making and planning, there will be a poorer visibility throughout the chain and invisible costs may be more difficult to uncover. Poor data quality data can lead to wrong inventory levels and give incorrect information on the location of the products, resulting in a skewed representation of the reality. This inaccurate image makes it more complex to uncover invisible costs and this will complicate the process of improving the manufacturer's operational performance.

4.3.3 Impacts due to convenience challenges

Most of the points that fall under the category of convenience challenges do not directly impact the operational performance. Nonetheless, that does not mean that their importance must be ignored. One aspect that can influence the operational performance is the lack of professional skills because it can lead to human errors. Human errors can impact the accuracy and the efficiency of the production. Humans may slow down production or make incorrect decisions or do wrong actions during their workday. Often it is the humans themselves who need to report these faults and it is likely that not all faults caused by human error are in fact reported as human error. Since not all of these faults are documented it can be difficult to identify them and improve the performance.

4.3.4 Collective impact of challenges on operational performance

Combining the impacts from all the challenges, it can be concluded that this will overall lead to both poor external and internal attributes. Poor external attributes include reduced delivery reliability, responsiveness and flexibility, while poor internal attributes include higher costs and reduced assets management efficiency (Dweekat et al., 2017). Each of the challenges will contribute to the external and the internal attributes in different ways, however the final consequences and impacts on the supply chain management will be the same. Managing all the three challenges correctly will maintain the costs low, and the assets management efficiency, the delivery reliability, the responsiveness and the flexibility will be high. Achieving this successfully will result in a competitive and sustainable supply chain and all the decisions must be made keeping these in the core, as illustrated in figure 1.

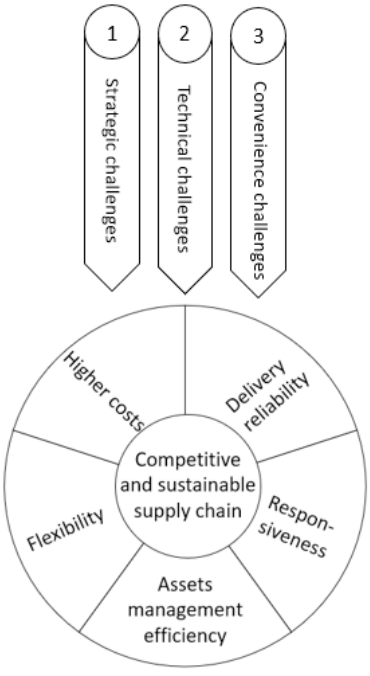

Figure 1. Framework illustrating how the three categories of challenges will impact the internal and external attributes and hence the overall supply chain performance.

5. CONCLUSIONS

There is no doubt that tracking and tracing technology leads to more real and representative data, and hence improves and facilitates decision making. Traceability eases control by

product monitoring and continuous process verification. The dairy industry is already a complex and challenging supply chain and if the trends continue the complexities are envisioned to increase due to increased competition and higher customer expectations. Complex, dynamic and unpredictable supply chains need to be resilient and having the competence of capturing, extracting and using high quality data and information will enhance the supply chain resilience (Leat & Revoredo-Giha, 2013).

Several challenges impede the application of tracking and tracing technology, especially from a manufacturer's perspective. Investigating these technologies shows that the strategic, technical and convenience challenges can be categorised as either adoption barriers or implementation barriers. Although these challenges vary amongst companies and different tracking and tracing solutions, the governing challenges tend to be deployment costs and lack of benefits. These reasons are particularly directed towards RFID technology and have led to manufacturers discontinuing RFID pilot projects.

This study concludes that physically implementing tracking and tracing technology does not tend to pose major difficulties, instead it appears to be aspects concerning organisational issues and security. Furthermore, being unable to manage these challenges successfully will have a direct implication on external and internal operational attributes. These attributes are essential to satisfy as they lie in the core of having a competitive and sustainable supply chain. Although the case company discontinued the RFID technology pilot project, both this manufacturer and others remain interested in exploring other solutions that will assist operational decision making.

If the current technological advancements continue, there will be an immense growth in connectivity, information sharing and transparency both internally within organisations and externally amongst supply chain partners. To facilitate the transition from the traditional supply chains we know today towards the connected and digital world which is forecasted it is essential to acknowledge the existing challenges and address them adequately. Therefore, future research should explore how these challenges can be overcome and in which cases and industries the discussed challenges are most predominant.

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