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Perspectives on Real-Time Information Sharing through Smart Factories: Visibility via Enterprise Integration

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***Abstract* — As per the Industry 4.0 vision, it is well established that 'Enterprise Integration' by inter-organizational collaboration in a supply chain can achieve competitive advantage for all the parties. However, not much study is done on the tools at the manufacturer's end that enable the real-time information sharing in between the integrated enterprises. This paper explores the role of manufacturing information systems (beyond ERP layer) to define the scope/role of smart factories to enhance 'visibility' (supply chain visibility). The findings contributed to developing a hypothesis that manufacturing operations management (MOM) systems, especially manufacturing execution systems (MES) of smart factories at 'manufacturer' can provide critical product-centric data to the 'wholesaler', thus enhancing supply chain performance. This position paper gives insights into the 'real-time information sharing' in the fresh food supply chain, by presenting the perspectives of both manufacturer (with MOM systems) and the wholesaler (with needs on real-time production data regarding shipments). Furthermore, it provides a conceptual model illustrating the scope of smart factories towards the manufacturing digitalization. Analysis explored through case example of a Danish meat manufacturer to investigate how MES tool can aid 'planning'. In addition, the paper also sets the agenda for future research in this area**

Keywords— Real-time systems, Enterprise information systems (EIS), Digital supply chains, Industry 4.0, Position paper

1. INTRODUCTION

1.1 Manufacturing Enterprise Information Systems in Industry 4.0

Industry 4.0 vision supports information-centric manufacturing and guides the manufacturing companies to acquire higher levels of digital capabilities to effectively utilize the available data. It necessitates the operations to take place by integrating systems along the supply chain. The integration (inter-organizational) of IT systems will result in improved planning and execution of supply chain activities, enabled by real-time information sharing. According to MESA international, MOM systems will provide critical information within the extended supply chain and MES is an enterprise information systems (EIS) in smart factories that operates in the MOM level (Level 3 as per ISA 95). It works as a decision support system with an objective to achieve process improvement as well as to improve supplier management. This, because MES enables product visibility throughout the ordering, manufacturing and delivery process.

1.2 Fresh Food Supply Chains

Cyber-physical systems (CPS) in manufacturing environments (such as - production facilities, smart machines, storage systems etc.) of Industry 4.0, will be capable of autonomously exchanging information, also resulting in improved supply chains through smart factories. This is applicable to all the industries including the 'food industry'. Food supply chains are unique mainly due to the handling of 'perishable products'. The increasing consumer demand for constantly available fresh food products at a low price [1] [2], makes the management of the different flows across the supply chain (demand, product and information flows) extremely important, entailing effective decision-making and efficient flows. One predominant way of ensuring this is through information-sharing [3]. Due to the short shelf life of fresh food products, certain information should preferably be available and shared in the supply chain instantly when the disruptive phenomenon arises (i.e. in real-time). This allows the entire supply chain to react instantly upon the disruption rather than later.

Much research exists on the information sharing in different collaborative supply chain strategies. Information shared in supply chains include historical sales data, point-of-sales data, inventory levels, upcoming campaigns, promotions, performance metrics, company plans, incoming customer orders, market product intelligence etc. Despite this, there remains a need for investigating real-time information empirically as "real-time accessibility of specific information needs of entities" [4]. An interesting stream of information in relation to this is down-stream from manufacturer to wholesaler. During the execution-level in fresh food supply chains, real-time information can be a critical necessity in case of e.g. a production break-down at manufacturer stage.

This study focuses on information sharing between a meat-manufacturers and a wholesaler. It aims to put forward perspectives on the need for sharing information in real-time using MOM systems. The relation between the two case studies in focus is illustrated in fig.1 (see grey area), in the entire supply chain context. Products flow from supplier through the different supply chain stages to the consumer (i.e. downstream), with the demand and cash flowing from

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consumer towards supplier (i.e. upstream). In between each stage information normally flows both upstream and downstream. In this study, the information sharing is delimited to concern downstream from manufacturer to wholesaler.

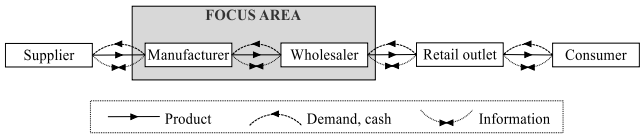

Fig. 1. Flows in between each stage

Section 2 describes the methodology and section 3 presents the outlook on real-time information sharing by presenting the perspectives. Section 4 discusses future research directions based on the preliminary iteration of the case study results, and concludes the position in section 4.

2. METHODOLOGY

This position study presents a selective literature review on MOM systems (of smart factories) in relation to real-time information sharing. The review results are used to explain how MES can enable visibility through real-time information sharing. Furthermore, core functionalities of MES that support this purpose were identified. The claims made based on the literature study were verified using an exploratory case study on one of Denmark's largest slaughterhouses (i.e. manufacturer) and the largest wholesaler. The case studies follow Flynn, et al. six-stage framework for conducting empirical research [5] about information systems support from manufacturer to wholesaler. Since the context and perspectives on real-time information systems are important to this study, an in depth study of the phenomenon in its natural context allowed good use of existing experiences [6] [7]. This allowed the study to reconcile evidence from observations and data with research literature. The cases contributed to empirically studying the needs of both the parties as well as their existing information systems.

First, a selective literature survey was conducted through 'google scholar' (database) with focus on latest research findings from the year 2010 - 2018. The key-words used in searching for papers are: 'enterprise information systems', 'MOM systems', 'smart factories', 'enterprise integration', 'traceability' 'supply chain visibility' 'manufacturing information', 'real-time information sharing'. This, to gain conceptual understanding on the manufacturing information systems support for integrated enterprises. A fresh food supply chain problem was considered due to the criticality of information relative to the short shelf life of some food products.

Second, two case companies were chosen within the fresh food industry. Due to commercial confidentiality, the manufacturer is called 'Company-A' and the wholesaler 'Company-B' throughout this article. Studying the secondary case company (company B) apart from the primary case company (company A), gave better understanding of the phenomenon.

- Company-A is one of the largest slaughterhouse in Denmark, handling pork and beef products. A centralized production facility in XXXX produces products to majority of the Danish meat market, including wholesalers, retailers, catering etc. Company-A's goal is to be a knowledge driven enterprise by making the best use of technology and information to deliver best services.
- Company-B is one of the Scandinavia's largest players within grocery and service trading, and is the largest grocery wholesaler in Denmark. Company-B supplies fresh meat products to more than 300 different grocery shops. Company-B's overall goal is to be known as the most value-driven company in Scandinavia, with deep focus on ensuring high quality (i.e. fresh) products constantly (i.e. minimal supply disruption).

Information and data about current information sharing and perspectives on real-time information sharing was gathered through semi-structured interviews with manufacturing IT-architect (from company-A) and product manager (from company-B). The duration of the interview with company-A was around 150 minutes, which was electronically recorded and transcribed. The collected information was analyzed and coded into various categories. The category of smart factories for 'demand and supply chain planning' is picked as a problem area to empirically study how manufacturing information sharing via external collaboration (enterprise integration) can improve supply chain performance.

3. FINDINGS – OUTLOOK AND POSITION

3.1 Status Quo

3.1.1. Enterprise Integration and Visibility in Supply Chains:

'Connected enterprises' is the term used to explain the digitally connected independent enterprises across the supply chains. The term also refers to e-business and information supply chains; all requiring real-time data sharing by connecting their information system elements [8]. Such a connected manufacturing enterprise is achieved by 'enterprise integration' where the information flow is made possible.

Operation visibility: With the enhanced digital capabilities of manufacturing enterprises, manufacturing operations can be planned, executed and controlled easily than before by enhancing traceability (being the ability to trace the history of all resources in the production process). On the other hand, to better the manufacturing processes, Industry 4.0 model is expected to fulfill the growing customer demands for faster real-time response by decentralized production control using MES to improve performance, quality and agility for globalized manufacturing businesses [9].

3.1.2. External Collaboration:

Information between the manufacturer and the wholesaler in supply chains is traditionally exchanged via bidirectional flows through EDI, fax, mail, internet and/or cloud. This exchange allows for attaching each supply chain stage together in relative degree [10], with information sharing considered a main part of collaboration.

"Rather than trying to independently project demand patterns, buyers and sellers share information in advance and work together to develop realistic, informed and detailed estimates that can be used to guide business operations" [11]. The level to which this is performed ultimately influences the supply chain success [12]. Hence, in the external collaboration context, sharing of information represents the exchange of any qualitative or quantitative data between any given supply chain stage and either downstream or upstream parties – i.e. manufacturer and wholesaler.

The below figure shows the inter-organizational (i.e. external) collaboration in the supply chain, between manufacturer and wholesaler (see fig. 2).

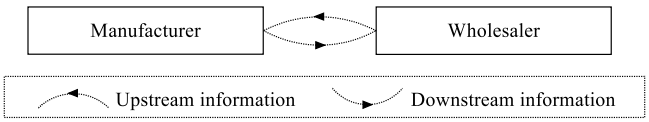

Fig. 2. Information flows in between Manufacturer and Wholesaler

3.2 Perspectives on Real-time Information

3.2.1 Wholesaler Receiving Information:

'Perishable products' deteriorate in quality through time, with limited shelf life down to few days (e.g. grounded beef and sushi). These products have requirements to handling and storage to reduce the speed of deterioration [13]. If not handled and/or stored properly, these products may deteriorate faster and to a level making the products dangerous for human consumption. In spite of the existing demand and supply chain planning models' (such as collaborative planning, forecasting and replenishment), the extent to which real-time data is actively used and reflected, still remains undiscovered for food distributors and retailers. This situation raises a need for reliable and constantly updated data, allowing all business functions to take decisions.

Further, product-centric data accessed by wholesaler through real-time systems, ensures constantly updated information about the products for the different supply chain parties. As example, for the wholesaler, real-time information from upstream stages (i.e. Manufacturer) about production break-down and possible scarcity in pending deliveries will allow the wholesaler to e.g. either try to source the products elsewhere in due time to minimize the impact on the customer (in the end, the consumer) – or distribute the available amounts across customers to ensure either supply to all customers or prioritized supply to customers. Today, information about over/under-supply in pending deliveries is typically exchanged through advanced shipping notifications (ANS), where the manufacturer informs about pending quantities to arrive at wholesaler. However, certain challenges exist in that the ANSs are sent when orders are dispatched, and not when the disruption arise – which may be several hours in advance. Hence, there is interest in applying diversified real-time data (on product and production information) for effective planning.

3.2.2 Manufacturer Providing Information:

Visibility through Smart factories: 'Information transparency' is one of the Industry 4.0 design principles as suggested by Hermann et al. [14]. As per the Acatech's vision for Industry 4.0, smart factories should have the ability to exchange information in real-time from one enterprise to another. Horizontal integration (as per production, Industrial automation and IT fields) is a strategy of integration of IT systems (also between different companies) to deliver an end-to-end solution [15].

MES of MOM systems is identified to serve visibility through smart factories, considering its functionalities and access to manufacturing information of the product from the shop floor. Robust manufacturing EIS like MES are believed to support the process by providing product-centric information. MES is an industrial software that has undergone gradual developments with the advancements that occurred in the computing technologies and integration levels. Next generation MES comes with an extended scope to provide 'all-round view' of all the resources involved in the production and can be described as a 'manufacturing cockpit'[16]. The tool has now evolved to provide faster real- time responses to match the customer demands [17]. MES is better equipped to provide the manufacturing information to any other enterprise in the supply chain, in case of a requirement. Such a detailed manufacturing information in real-time is only available with MES but not with 'Enterprise resource planning' (ERP) tools that operates in the business management level (as per figure 3). SCADA of Level 2 is confined to the controlling of the equipment movement, whereas MES can control the overall production activity. Hence, SCADA systems can only track equipment level information but MES can track the production process information.

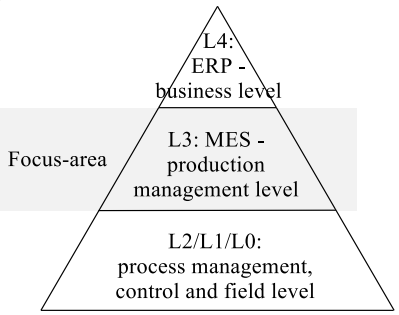

Fig. 3. ISA 95 Levels of functional hierarchy in a manufacturing enterprise [18]

Enterprises are required to look beyond their internal processes by extending their information systems to integrate with the partners of the supply chain. Even though linking ERP systems of different enterprises to achieve the inter-organizational information exchange is a popular method, ERP might not be able to provide an in-depth real-time information of the product to support the 'planning' issue in the supply chain. Most ERP systems operate on historical data in the inter-organizational integration setups and the existing enterprise integration solutions have difficulty in addressing this issue.

Product level information at the manufacturer end is captured by the Level 3 systems (level as per the ISA 95/IEC 62264 standard) of MOM layer of the shop-floor. MOM is predominantly supported by the MES, whose scope extends to scheduling and product delivery. Below are the 11 functionalities of MES, as per MESA International. In this paper, 3 functionalities of the 11 are identified to have links to supply chain management:

i. Operations/ Detailed scheduling

ii. Dispatching production units (real-time dispatch information on the factory floor tracked and flows are managed as jobs, orders, batches, lots and work orders)

iii. Product tracking and genealogy (on line visibility of the product status – component materials by suppliers, live production conditions, rework etc.)

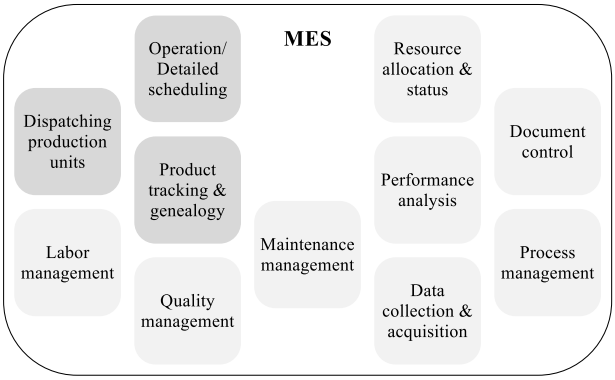

Fig. 4. 11 functionalities of MES according to MESA International

The above mentioned feature of live tracking of the production conditions and exchange is not available at the enterprise level with ERP systems, in contrast to MES. Hence, MES is more equipped to provide the real-time information on the product to the wholesaler (to aid planning). Moreover, MES also promotes 'collaborative manufacturing' better than ERP, as it can provide traceability on the unit level and has an ability to give live production status reporting. "Collaborative manufacturing is to automate, link, complement, or support business processes across departmental, plant, enterprise, or supply chain boundaries [19]".

Software systems are the enablers of responsive supply chains (see fig. 6) and this model is supported through smart manufacturing using MOM systems like MES.

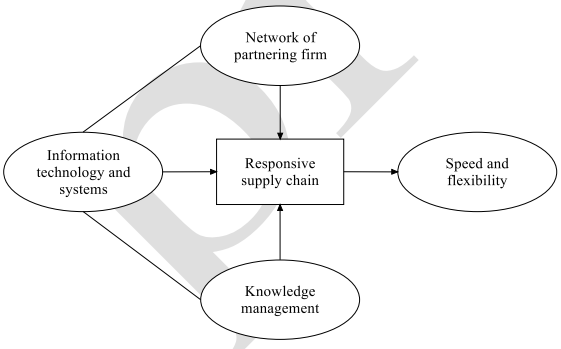

Fig. 5. A responsive supply chain framework (Gunasekaran et al. [20])

With an objective to achieve supply chains that are flexible and responsive, MES is believed to provide real-time product-centric information to help the planning of wholesaler in collaborative manufacturing, achieved through inter organizational integration.

3.3 Claims

The qualitative analysis of literature as well as the case study of manufacturer and wholesaler helps in deducing that:

- Interdependencies on exchange of real-time manufacturing information exist as per the above two perspectives
- Defining the needs of the wholesaler is an important step to know what kind of information is to be provided by the manufacturer using MES, which results in collaborative manufacturing achieved through smart factories
- Providing real-time information on 'machine downtime' and 'failures on behalf of suppliers' is interesting for a manufacturer to meet the customer demands (customer of the manufacturer being wholesaler) and to simplify the methods of communication
- Receiving real-time manufacturing information is interesting for a wholesaler to react faster to any disruptions in supply from the manufacturer

The first iteration of the case study results are discussed in the following section 4, below. The preliminary analysis of the case study findings contributed to empirical verification of the theoretical propositions (based on the selective literature review) of section 3.2 and to further deduce the claims in section 3.3.

4. Results And Discussion

This study was done with an expectation to explore how smart factories can effectively exchange real-time information using MOM systems. It gave an understanding on the interdependencies of the enterprises and the purpose of having enterprise integration in the industry 4.0 context. Furthermore, it gave insights on how MES can act as a real-time system to enable such connectedness by providing information on flow of materials and manufacturing cycle times.

Practical Issues Surrounding the Vision: From the preliminary qualitative analysis of the interview of Company-A, it is understood that there is skepticism in having real-time systems such as cloud based MOM systems. This, due to the fear that manufacturer might face operating performance issues if the production stands still, in the case of a technical problem on cloud.

Challenges of Real-time Information Sharing: Real-time data sharing is easier with cloud-based MOM solutions. But, companies are interested in weighing the achievements of having cloud-based solutions against having a server onsite. More over systems integration of different enterprises also arises doubts on trust and security of data.

Future Research Directions: The expanded version of this paper requires an in depth analysis (second iteration) of the qualitative interview of Company-A with a problem based learning (PBL) approach. Problem being the supply chain planning and learning is expected to be achieved on MES (and other MOM software) as real-time systems. This to evaluate its functionalities that aid enterprise integration and visibility. The future work intends to evaluate the effectiveness of the proposed collaboration and integration using MES on the real-life industrial case of Company-A and

Company-B to verify initial empirical findings by conducting second round of interviews for a qualitative synthesis. A future explanatory study that is empirical in nature could answer how 'real-time information sharing' (including upstreaming) is achieved through MES to resolve risks caused due to the issues of coordinating supply and demand in the supply chains.

5. Conclusion

This position paper is written based on the existing literature study on the concepts, along with preliminary (qualitative) analysis of a case example. The position taken helps in concluding that –

- There is a need for exchanging real-time information between supply chain parties because it is vital for realizing the concept of 'enterprise integration' for Industry 4.0

- To contribute to the field of manufacturing information systems, it is essential to investigate the need to use real-time systems like MOM systems/ MES (beyond ERP)

- MOM systems are central to smart factories for 'visibility' and their scope is presented through a conceptual model in the fig. 4

- MOM systems (predominantly MES) can provide real-time product data to the wholesaler, resulting in the improvement of supply chain performance

For theoreticians, this exploratory research paper gives insights into MES/MOM as real-time systems and enabling technologies for supply chain transformation. Future research directions could include trying to understand the benefits of MES across different industries, how the use of real-time information sharing through MES impacts total supply chain performance, as well as how real-time information sharing can be applied specifically to the three functionalities of MES described in this study.

For practitioners, the perspectives on manufacturing information sharing of 'manufacturer' to 'wholesaler' in the context on Industry 4.0 are presented. Research findings guide the design of factories of the future by prioritizing 'external collaboration' for digital supply chains to have productivity improvement in the business operations.

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